

UNITED STATES OF AMERICA
NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

PUBLIC HEARING
AMERICAN AIRLINES FLIGHT 587
AIRBUS A-300-600 (N14053
BELLE HARBOR, NEW YORK
November 12, 2001
DOCKET NO: DCA-02-MA-001

VOLUME III
Thursday, October 31, 2002
8:00 a.m.

APPEARANCES:

National Transportation Safety Board

CAROL CARMODY, ACTING CHAIRMAN
JOHN J. GOGLIA, MEMBER
JOHN HAMMERSCHMIDT, MEMBER
GEORGE W. BLACK, MEMBER

HEARING OFFICER

LORENDA WARD

Technical Panel

STEVE MAGLADRY
JOHN CLARK
JOHN O'CALLAGHAN
DAVE IVEY
MALCOLM BRENNER
ROBERT BENZON
BRIAN MURPHY
DR. MATTHEW FOX
DR. ALAN KUSHNER

Parties

CAPTAIN DONALD W. PITTS, ALPA
DR. JOHN LAUBER, AIRBUS
HAROLD DONNER, FAA
PIERRE JOUNIAUX, BEA
ROBERT AHEARN, American Airlines

I N D E X

<u>WITNESSES:</u>	<u>PAGE:</u>
MICHEL CURBILLON Department Manager, Loads and Dynamics Airbus	729
UWE KERLIN Local Domain Manager Germany Loads and Aeroelastics Airbus	729
BERND RACKERS Senior Manager, Composite Technology Airbus	811
DR. LARRY ILCEWICZ Chief Scientific and Technical Advisor - Composites FAA, Renton	861
ERHARD WINKLER Senior Specialist, Composites Airbus	924
DR. WILLIAM (BILL) WINFREE Senior Aerospace Engineer NASA Langley	987

1 P R O C E E D I N G S

2 8:06 a.m.

3 ACTING CHAIRMAN CARMODY: Good morning.

4 Please take your seats. I'd like to get started.

5 Thank you.

6 Good morning. Let's proceed. I see the
7 witnesses are seated. Ms. Ward, would you introduce the
8 witnesses, please?

9 MS. WARD: We have Mr. Michel Curbillon and
10 Mr. Uwe Kerlin. Please raise your right hand.
11 Whereupon,

12 MICHEL CURBILLON
13 having been first duly sworn, was called as a witness
14 herein and was examined and testified as follows:
15 Whereupon,

16 UWE KERLIN
17 having been first duly sworn, was called as a witness
18 herein and was examined and testified as follows:

19 MS. WARD: Thank you. Please have a seat.

20 Mr. Curbillon, could you please state your
21 full name, your current employer, and your business
22 address?

23 MR. CURBILLON: My name is Michel Curbillon.
24 My employer is Airbus, and the address is (French
25 address) in Toulouse.

1 MS. WARD: And what's your current position,
2 and how long have you been in that position?

3 MR. CURBILLON: My current position is Loads
4 and Dynamics Manager in Airbus, and I am in this
5 position since 1995.

6 MS. WARD: And what are your current duties
7 and responsibilities, and actually, can you please
8 state any education and training that you have received
9 that qualifies you for your current position?

10 MR. CURBILLON: My current position is a dual
11 position which covers two main subjects. The first one
12 is an overall loads product coordinator within Airbus
13 across all programs, and the second one is to act as
14 technical advisor to Loads Engineering, and my
15 education is I'm a graduate from French Engineer School
16 in General Mechanical Engineering and where I got a
17 degree, and I got an additional degree on Aeronautical
18 Engineering which is equivalent to a Master Degree in
19 the American system.

20 MS. WARD: Thank you, Mr. Curbillon.

21 Mr. Kerlin, could you please state your full
22 name, your current employer, and your business address?

23 MR. KERLIN: My full name is Ewe Ernest
24 Kerlin. I'm employed at Airbus Germany in Hamburg in
25 Germany.

1 MS. WARD: And what is your current position,
2 and how long have you been in that position?

3 MR. KERLIN: Since 2001, the position is the
4 so-called Local Domain Manager for Loads and
5 Aeroelasticity in Germany.

6 MS. WARD: Could you briefly describe your
7 duties and responsibilities and the education and
8 training that you may have received to qualify you for
9 your current position?

10 MR. KERLIN: I have a degree which is
11 equivalent to the Master Degree of the University of
12 Brunswick as an Aeronautical Engineer. I started in
13 Airbus in 1987, at that time in a company called MBB.
14 I started as a development engineer for Component Loads
15 Analysis and worked for nearly all Airbus Programs. In
16 1991, I took more and more responsibility in the
17 coordination of work for Special Airbus Transporter.

18 Beyond that, I was involved in the
19 certification of that aircraft in 1995, and starting
20 with 1996, I became the head of the Domain of Dynamic
21 Response Analysis where I was mainly responsible for
22 the Gust Loads Analysis carried out at the Germany
23 site, and in 2001, I became the so-called Local Domain
24 Manager as I said before.

25 MS. WARD: Thank you, Mr. Kerlin.

1 Madam Chairman, I find these witnesses
2 qualified and I now turn them over to Mr. Brian Murphy
3 for questioning.

4 ACTING CHAIRMAN CARMODY: Thank you.

5 Mr. Murphy, please go ahead.

6 EXAMINATION

7 MR. MURPHY: Good morning, gentlemen.

8 I'd like to discuss the following topics with
9 you today: Certification basis for the -600R from a
10 loads point of view only, the design loads for the
11 vertical stabilizer on the -600R, and the AA-587 and
12 AA-903 loads assessments.

13 Madam Chairman, Mr. Curbillon and Mr. Kerlin
14 have prepared some overview material for us, and if
15 they could present that at this time.

16 MR. CURBILLON: Thank you, Madame Chairman.
17 Good morning.

18 So we will start this presentation by an
19 overview on the loads and, generally speaking, on the
20 loads acting on the vertical airplane. For this
21 presentation, we will address several topics which will
22 give you this view on loads, the structural condition,
23 the envelope loads figure, and also short information
24 on rudder usage, and also the FAR/JAR requirements, and
25 also the American Airlines 587 General Analysis, and

1 we'll finish by a loads summary.

2 Starting with the general information on
3 loads and to try to understand the loads development in
4 flight when an aircraft is subjected to different type
5 of loading. So, the first one is linked with
6 aerodynamic loads which are due to the pressure which
7 developed around the external surfaces.

8 The second type of loading we have are the
9 initial loads, those which are due to gravity or
10 acceleration which could be applied on the different
11 items of mass which are distributed all along the
12 aircraft.

13 You have also the propulsion loads coming
14 from the engine thrust and, in some cases, you may have
15 some specific type of loading, like the pressure, for
16 example, in the cabin pressure or cargo, when they are
17 pressurized.

18 For calculating the loads, we consider all
19 the significant forces which act on the airframe and
20 those loads are calculated for a number of specific
21 conditions. We call those conditions load cases which
22 are defined with reference to the requirements.

23 As far as the requirements is concerned, the
24 Airbus aircraft are designed and certified against
25 requirement FAR and JAR 25 which are related to

1 transport category airplane. Each load case is defined
2 by two significant parameters. The first one is the
3 conditions, what we call conditions. Is it a maneuver,
4 coming from the pilot or the -- is it also the result
5 of an atmospheric disturbance, a gust? This is a
6 condition. And second, we have also to define the
7 domain, where we apply this condition, in terms of
8 speed, altitude, and for which aircraft weight and
9 center of gravity. In the domain, where the aircraft
10 may or will operate.

11 As far as the vertical tail loads are
12 concerned, several conditions dictate the establishment
13 of the vertical tail load, and those conditions, the
14 main condition, are the yawing maneuver resulting from
15 a regular displacement condition which are defined in
16 the Requirement 25.351(a), the lateral forces resulting
17 from the aircraft encountering an atmospheric
18 disturbance, like gust, which are defined in the
19 Requirement 25.351(b), the engine failure and loss of
20 thrust with the associated pilot correction, which are
21 defined in 25.367, and also the potential system
22 failure, and we have, of course, main thrust on flying
23 control systems.

24 As far as the industry domain is concerned,
25 the flight domain. The flight domain is defined -- is

1 defined by the speed of the aircraft and the altitude.

2 So, it means the aircraft may operate at a speed and a
3 given altitude. To run our loads calculation, we first
4 define what we call design speed. We have the minimum
5 control design speed, the maneuvering speed, the speed
6 DB operating in the gust condition, the gust speed, the
7 VC, which is the cruising design speed, and the VG,
8 which is the design dive speed. Those speeds are
9 defined in agreement with the requirement which is at
10 25.331, and you can see on these graphs the position of
11 the speed, the minimum control speed, the cruising speed
12 which is this blue line, and the diving speed which is
13 above the cruising speed, which is the speed for which
14 we run the calculation for the loads establishment.

15 The requirement requests us to run our
16 calculation to cover the overall flight domain and the
17 conditions, for example, for the yawing maneuver
18 requests us and we have seen that yesterday with
19 reference to the requirement between VMC and VD for all
20 altitude where the aircraft will operate. So, there
21 are four defined conditions, for example, at this point
22 where we define an altitude and a speed and it is a
23 point of calculation and you can see here a type of
24 mapping we use to run our load calculation to cover the
25 overall domain. For example, for gust calculation

1 request to be performed at VB, VC, and VD, and the
2 calculation expended above the operational domain. For
3 example, for the high speed, the operational domain is
4 limited by the speed of VMO, which is the maximum
5 operating speed. This speed must be below VC, which we
6 cover with our calculation, up to VD.

7 The second condition which is important for
8 the domain to be investigated is the mass and CG. We
9 have to cover as per requirement all possible
10 combinations of fuel and payload, covering as well the
11 design weights of the aircraft up to the maximum take-
12 off weight which is for this aircraft 375,890 pounds,
13 and we have to cover also the range of center on
14 gravity which could be achieved by the different kind
15 of loading in terms of payload and fuel from forward
16 limits to aft limits, and as an overall view, for one
17 mass condition and we have defined to cover the full
18 range of center of gravity and weight around 30
19 different mass cases with different payload
20 distribution, different fuel distribution, for each
21 individual mass case, we run the loads calculation for
22 the overall flight domain and repeat after for in this
23 case to run again the loads calculation for the flight
24 domain.

25 To run this loads calculation, we use a

1 mathematical model. This mathematical model involves
2 input data like aerodynamic data which are coming from
3 wind tunnel tests or derived from wind tunnel tests,
4 mass distribution for all the items of mass which are
5 distributed along the aircraft, put through all
6 stiffnesses coming from the Structure Department, the
7 engine data in terms of thrust, and the system data,
8 like the RTL system.

9 All those input data are fit into a loads
10 model and this loads model alert us to calculate the
11 airplane movement and the associated loads. The
12 airplane movement may result from a maneuver, for
13 example, a rudder maneuver, but we have other type of
14 maneuver in longitudinal, or from atmospheric
15 disturbances encountered by the airplane during the
16 flight, and as a result, we calculate the airplane
17 component loads.

18 This model, this overall model, is supported
19 by several type of tests, ground, like ground vibration
20 tests, flight tests, flight tests with some of the full
21 loads, and shearing and that creates representation of
22 the aircraft area. By using this model, we run the
23 simulation for the conditions which are requested by
24 the JAR requirement. So, we make necessary analyses,
25 and we calculate the movement of the aircraft and the

1 forces which apply on the aircraft and from those
2 forces, we define the loads on the different components
3 of the aircraft, like wing, tail, and for the vertical
4 tail as well as for the wing, for example, those loads
5 are represented by shear. So, it means you have a side
6 force and you can represent the shear total, for
7 example, as bending moment resulting from the side
8 loads with the level harm against the reference for the
9 route here and/or the torsion loads around the
10 reference axis at the different station where we
11 calculate those loads. Those loads are later on used
12 for structural analysis as well design and
13 certification and structural tests.

14 Now, you have seen that we have several
15 conditions. We have a domain, and for each individual
16 condition, like yawing maneuver or gust, we run the
17 calculation for each individual condition, for all the
18 flight conditions, all the mass condition, and we
19 select through a selecting process the most severe
20 combination of all those parameters which give the
21 various loads, for example, for the yawing maneuver,
22 the engine failure, and the gust, and those individual
23 loads are called envelope loads for the condition gust,
24 yawing maneuver, and after that, we consider each
25 individual case and the highest value of all of these

1 individual cases gives what we call the limit loads.
2 Therefore, the limit loads at the end is the most
3 severe loads condition which results from a very large
4 number of cases as we have already described to you.

5 What are we doing with those loads? Those
6 loads are used for the structural analysis and the
7 strengths requirement specifically in terms of limit
8 loads, the maximum loads to be expected in service, and
9 we have defined those loads as we have explained
10 before. The ultimate loads, which are the previous
11 limits loads, multiplied by a prescribed factor of
12 safety, generally 1.5, and we lose loads, so we must be
13 able to support the limit loads without permanent
14 detrimental deformation and also to sustain the
15 ultimate loads without failure, so the structure will
16 not collapse, and as a result of all this set of
17 required conditions, it provides an appropriate level
18 of structural strengths and this result is the overall
19 process which show equivalency between usage purposes
20 of transport category aircraft, for example,
21 requirements associated with this type of aircraft,
22 design, test, and the usage.

23 If now you would like to have the figure on
24 the envelope loads on the vertical tail plane of the
25 A300-600R, as an example, we'll show you the

1 vertical tail bending moment at root. The limit load
2 is obtained by the gust conditions when you use as a
3 reference one. The yawing maneuver gives us a level of
4 load which is .8 limit loads. The ultimate loads are
5 the limit loads multiplied by a factor of 1.5, so we
6 obtain 1.5, and I presented before, it is the strength
7 which is prescribed by the requirement for the
8 structure. As far as the A300-600 is concerned, we
9 have run full-scale static test for structure which has
10 demonstrated a level of strength of 1.93 times the
11 limit loads.

12 Now, if we come back to the rudder usage,
13 this has been presented early at the beginning of the
14 -- by the first witness, but just to recall that the
15 usage of the rudder, if you deflect the rudder during a
16 flight, it will result to a yawing movement. This
17 yawing movement is the result of the loads coming from
18 the rudder deflection. Those loads are loads which are
19 induced on the vertical fin by the rudder deflection.
20 Those loads create a yawing movement represented by the
21 sideslip which itself induced on the fin a set of
22 lateral forces, and you can see that in this case, the
23 lateral forces are opposite.

24 The second type of usage of the rudder is to
25 oppose the effect of the engine thrust asymmetry coming

1 from an engine failure, and in that case, the rudder
2 deflection creates induced forces on the vertical tail
3 which oppose to the asymmetry coming from the thrust of
4 only one engine.

5 Coming back to a very important case, the
6 yawing maneuver, this has been already discussed
7 yesterday with the witness. So, therefore, I will not
8 spend too much time on that, but I will explain again
9 anyway. Starting from a level normal flight condition,
10 the requirement asks us first to have a full abrupt
11 displacement of the rudder to a stop. This is Case
12 Number 1 which is related to the part of the
13 Requirement 25.351(a). At this time, due to the sudden
14 displacement of the rudder, you induced on the vertical
15 tail plane side loads due to the rudder deflection.
16 Due to this rudder deflection and the associated
17 induced loads, the aircraft starts to yaw, it is a red
18 curve, against time. The rudder deflection is
19 maintained, and the -- due to the dynamic nature of the
20 movement, the sideslip develop, goes through a maximum
21 sideslip which is called oversweep, and later on, due
22 to the natural stability of the aircraft, the sideslip
23 develop and achieve a steady sideslip.

24 During this phase and before we lose the time
25 around maximum sideslip or whatever is the position,

1 the loads which apply on the vertical tail then could
2 be described as follow: still there is a deflection
3 with the loads as at the beginning, but due to the
4 yawing movement of the aircraft and the associated
5 sideslip, there is also induced -- some forces induced
6 on the vertical tail plane due to the sideslip, and
7 those loads case are opposite, and when the sideslip is
8 stabilized, there is a request to return suddenly the
9 rudder to neutral, and at that time, for this third
10 condition which is defined by the Requirement
11 25.351(a)(3), the rudder is returned to neutral and the
12 resulting forces on the vertical tail plane are only
13 those induced by the sideslip, knowing that the rudder
14 is to neutral.

15 If we look now on the development of the
16 movement of the aircraft, you recognize the rudder as
17 before, the associated sideslip, and if we look to the
18 development of the loads, the loads induced on the
19 vertical tail by the rudder deflection are the blue one
20 versus time. The loads of the side force induced by
21 the sideslip are here, it is the red curve, and the
22 total side force which results on the vertical tail
23 plane is a green line. At the beginning, as the
24 sideslip has not yet developed, the loads induced by
25 the sideslip are small and we are nearly at the level

1 of the side force induced by the rudder, and as the
2 loads are opposite, you have the green development and
3 at the end again, and if now we consider the -- what we
4 call the loads in terms of bending moment at route, the
5 bending moment development versus time shows this type
6 of evolution and we made the calculation in a partial
7 manner all along the time, and in our searching for
8 sets to get some maximum force and minimums of the
9 loads, we look -- all the loads erupt in terms of time,
10 and we select just one and you can see that this one,
11 this one, and this one are high loads and we select the
12 highest one for this condition. We repeat the
13 condition for normal flight condition, for all the mass
14 condition, and at the end, the highest one is the
15 envelope of the individual case.

16 Now, going to the American Airline 587
17 accident, so since this accident, we have concentrated
18 our effort to analyze and to understand the accident,
19 and for this purpose, we, loads community, have
20 concentrated our effort on the last 12 seconds of the
21 flight as indicated on the DFDR, and we have calculated
22 the loads, taking into account the time history of the
23 rudder development and as well from the other
24 parameters derived from the DFDR, like the aircraft
25 movement.

1 First, the rudder movement. Here you have
2 the time, the rudder deflection during the last 12
3 seconds of the flight, and you can see that the
4 movement, the rudder movement, is cyclic and rapid with
5 abrupt, full abrupt displacement. There's back-to-back
6 reversal, one, a second one, third, fourth, and fifth.

7 This is the traces you have seen from the previous
8 witnesses.

9 Now, if we look at loads on the side, the
10 aircraft movement development, the rudder deflection is
11 in blue, the associated movement of the aircraft in
12 terms of sideslip is represented in red. The first
13 view shows that the sideslip value increased with the
14 time, according to the rudder movement. Now, if we
15 look at the side forces induced on the vertical tail
16 plane during the time, you will recognize in blue the
17 lateral forces induced by the rudder movement. In red,
18 the side forces induced by the sideslip which also
19 increased with time, and you will notice that according
20 to the phasing of the movement, you have the sideslip
21 loads and the rudder forces which are additive here.
22 For example, rudder plus sideslip give total forces as
23 well at the last second of the flight, and what
24 happened in terms of loads and we take into account for
25 this purpose the bending moment on the vertical tail

1 plane and its root. Here you have the development of
2 this value against the time.

3 The green curve is the limit loads on both
4 sides, positive and negative. The green -- sorry. The
5 red curve represents the ultimate loads, 1.5 times the
6 limit one, and you can see the first -- the first input
7 of the rudder, so loads develop and remain below the
8 limit loads. When you have the first reversal, we are
9 at the range of limit loads. We start again a second
10 movement. We are still inside the limit loads, and
11 when we start the first movement, we exceed the limit
12 loads and we are at the level of ultimate, and when we
13 start the movement of the rudder deflection, the loads,
14 the bending moment at route move again in usual
15 direction, across the limit loads, cross the ultimate
16 and achieve a very high level which is in the order of
17 magnitude of 1.93 limit loads. This value is the value
18 we have demonstrated on the fatigue test rupture which
19 will be described more later by the -- the -- the
20 Airbus colleague and it is really -- this value
21 represents the static strengths of the vertical tail
22 plane.

23 That's the load summary. The A300-600
24 vertical tail plane has been established in agreement
25 with the special requirement for transport category

1 airplane. We demonstrated that you present structural
2 model about requirement, so the full-scale static test
3 results, and as far as the American Airline 587 loads
4 are concerned, the aircraft's rudder movement during
5 this flight create very, very high loads on the
6 vertical tail plane which exceed the design loads of
7 the vertical tail plane due to the cyclic movement and
8 the shape of the movement and the amplitude of the
9 movement and the timing of the movement. Here, the --
10 if you -- to support this sentence, recognize here's
11 the movement of the rudder. You have the yawing
12 maneuver. For the most severe case, which is at around
13 200 knots, knowing that the American Airline flight
14 accident appeared around 214 knots, there is the same
15 deflection, and at 200 knots, that deflection is
16 bigger, and if you compare to the load results in those
17 two calculations, the thin red line represents the
18 loads of the yawing maneuver for the condition. The
19 movement of the loads for the American Airline accident
20 and you can see that the loads exceed again
21 significantly the design loads limit and the ultimate.

22 This is the end of my presentation and thank
23 you for your attention.

24 MR. MURPHY: Just two points I wanted to --
25 to make on that then, Mr. Curbillon.

1 The sideslip and the rudder deflections for
2 certification actually relieved the net load on the
3 tail?

4 MR. CURBILLON: Yes.

5 MR. MURPHY: Okay. And then, during the
6 accident scenario, they were in fact additive from --

7 MR. CURBILLON: Yes.

8 MR. MURPHY: -- Points 2 through 5, but at
9 the first input, it would have behaved as it would for
10 the certification maneuver?

11 MR. CURBILLON: You are -- that's correct.

12 MR. MURPHY: Okay. Could you briefly
13 describe for us the history or the evolution of the
14 loads development programs from the B2B4 up through the
15 -600R?

16 MR. CURBILLON: Yes. If you would like to
17 have that in very simple manner? So, the -- these two
18 aircraft, we start with the A300-B2 which was certified
19 in '74. We have a new version called B4 which has been
20 certified in '75. After that, we have developed new
21 aircraft which is the A310 and the first version was
22 called -200. This version was defined and certified in
23 '83. Later on, we have developed the A300-600 which
24 was certified in '84, and there were some -- already
25 some commonality between the two aircraft, and next, we

1 developed the A310-300 which was certified in '85, and
2 we have also developed again the A300-600, called 600R,
3 which has commonality between the two planes, for
4 example, the fin, to achieve the certification date in
5 '88.

6 What I would like to highlight is that these
7 programs, even there is some industry commonality, even
8 there is some common component. Each individual
9 program, like the 300-600R by itself, has been
10 considered as a unique program as far as loads are
11 concerned, and we have produced a full set of loads
12 analysis and we have produced a full loads
13 certification document which is dedicated to this
14 version. We have done the same thing for an A310-200
15 and A300-600 and A310-300. Each in the program has
16 been considered individually to run the full loads
17 calculation.

18 MR. MURPHY: And the -600R maneuvering gust
19 loads, I may have missed it when you just summarized
20 it, but the -600R actually were contained within the
21 310-300 design envelope?

22 MR. CURBILLON: Yes. As far as the fin is
23 concerned, yes.

24 MR. MURPHY: Okay.

25 MR. CURBILLON: But again, the loads on the

1 fin coming from the two program are, I would say,
2 contain -- the 600 is contained as the 310, but it's
3 not very large difference anyway.

4 MR. MURPHY: Okay. During these loads
5 calculations, from a loads point of view, and then
6 obviously passed on to the structures community, is the
7 yaw damper on or off for these calculations?

8 MR. CURBILLON: The -- for the loads
9 calculation on the 600R, the yaw damper is off.

10 MR. MURPHY: So, no relief through the whole
11 --

12 MR. CURBILLON: We don't take the yaw damper
13 into account that calculation.

14 MR. MURPHY: Okay. If we could, there's
15 another exhibit that's -- it's fairly short in length,
16 but I think it would be helpful -- actually, I take
17 that back.

18 If you could get referred to the design
19 envelope on Exhibit N, Page 5, and just describe that
20 -- that graph and its use?

21 MR. CURBILLON: Exhibit N?

22 MR. MURPHY: Exhibit N, Page 5.

23 MR. CURBILLON: Page 5.

24 MR. MURPHY: It should be the design
25 envelope.

1 MR. CURBILLON: 75. Yes, what is your
2 question related to this?

3 MR. MURPHY: Just -- just for clarification,
4 explain the envelope, its intent, its purpose, what its
5 used for.

6 MR. CURBILLON: Okay. May I use a previous
7 slide just to explain from where it's come from?

8 MR. MURPHY: That's fine.

9 MR. CURBILLON: If you take into account, for
10 example, a yawing maneuver, I would not come back to
11 the rudders or sideslip. This is the time you have the
12 development of the three main loads. In red, the
13 shear. In green, the bending. In blue, the torsion.
14 You can represent those loads versus time.

15 But we also are able to represent the loads
16 evolution in the two-dimension drag arm where you have
17 the torsion and vertical and the bending. At the
18 beginning of the maneuver, you are there. When you
19 move the rudder to the stop, the bending moves that
20 torsion as well. After that, the sideslip establish,
21 go to the sideslip. You return to the rudder to
22 neutral and the aircraft is coming back to normal
23 situation.

24 From those cases, this type of
25 representation, we gain one calculation, and we obtain

1 again the torsion versus bending. We obtain here the
2 envelope for the yawing maneuver limit. If you
3 multiply this envelope by 1.5, you obtain the envelope
4 ultimate for the yawing maneuver, and as you can induce
5 maneuver on the right or on the left, you have a
6 statistical aspect, and here, you have the disparate
7 gust results in terms of bending and shear limit
8 condition, and if you multiply by 1.5, you obtain the
9 ultimate loads.

10 MR. MURPHY: I think you've described very
11 well the factors that lead up to the maneuver. This is
12 just going back to some -- some thoughts from yesterday
13 on the gust condition.

14 The gust case, that limit load data point
15 there. The turbulent air speed, flight through
16 turbulent air speed, DB, and the lift slope curve, CY
17 Beta there, they're fairly important factors in
18 calculating the gust loads?

19 MR. KERLIN: Yes, that's right.

20 MR. MURPHY: Okay. Now, if I were to
21 increase the DB speed by 20 knots and the lift slope
22 curve appreciably, would that change that limit load
23 data point then?

24 MR. KERLIN: That would change it, yes.

25 MR. MURPHY: So, it's very dependent on then

1 those two parameters greatly then for any given
2 airframe?

3 MR. KERLIN: Yes.

4 MR. MURPHY: Okay. Thank you.

5 On that figure -- if we can go back to that,
6 please? Could you just for us, on the design envelope,
7 just show us where 351A, B and C would be?

8 MR. CURBILLON: So, if we show this envelope,
9 the 351A is giving this envelope, 351B gives this
10 point, and if we go to 351A, the .1 is there. It's at
11 the time where you have the maximum deflection at the
12 beginning of the event. The .AB2 is a point in this
13 area, and here is a .B -- sorry -- A3 which is a return
14 to neutral and observed the aircraft with this natural
15 stability which come back to the result sideslip.

16 MR. MURPHY: Okay. Understanding that these
17 are not certification requirements, the next question,
18 I discussed yesterday with the gentleman from the FAA
19 the effect of returning the rudder at max sideslip and
20 -- and also the effect of performing a doublet at
21 steady state. Could we put that graph back up?

22 Is it possible, knowing that you don't have
23 calculated figures maybe or maybe you do, can you
24 indicate what that would do to the shape of that design
25 envelope?

1 MR. KERLIN: Maybe we can come back to the
2 previous slide, which gives a slightly more better
3 impression.

4 The return from -- from Beta Max, which is
5 reached here at .2, would then go this direction. So,
6 it would lead to a little bit higher loads. That is
7 the condition what we call the Russian, the Russian
8 type of maneuver, because it's contained in the Russian
9 Certification Basis, and on the other side of the
10 tablet, a better stabilized condition would again start
11 at .4. It would go in that direction but not only to
12 this point but farther -- further on in -- in that
13 direction because of the reversal of the rudder and not
14 to stop at zero rudder deflection.

15 MR. MURPHY: Okay. Thank you very much, Mr.
16 Kerlin.

17 If you'd go to the next graph, the next
18 slide, please? Could you -- I'm sure you know it
19 probably from the top of your head. Could you indicate
20 the three points that I asked -- we -- the NTSB asked
21 you to analyze for the accident and show where roughly
22 -- approximately where they would fall on that graph?

23 MR. CURBILLON: The American Airlines
24 accident?

25 MR. MURPHY: Yes, please.

1 MR. KERLIN: We have a slide for that.

2 MR. CURBILLON: We have a slide for that. It
3 will show you just where we -- the accident will be in
4 this area.

5 MR. MURPHY: Okay. That's fine. Does
6 anybody want to see the actual slide, if they can
7 produce it, or is that sufficient? You would? Okay.
8 Could you find that, Mr. Curbillon?

9 MR. CURBILLON: Here.

10 MR. MURPHY: Actually, now that I see where
11 you've gone with that, why don't we -- why don't I just
12 ask you -- I'd prefer then if you would just present
13 the material, the accident loads assessment, in Exhibit
14 P. That would be beneficial.

15 MR. CURBILLON: Okay.

16 MR. MURPHY: Thank you.

17 MR. CURBILLON: So, the analysis of the
18 American Airline 587 loads assessment, to run this
19 loads assessment, we have, I would say, used the two
20 methods which have been presented to you on Tuesday by
21 the first witnesses, and these two methods are the
22 following.

23 The first one is what we call the simulation
24 methods. In that case, we calculate the aircraft
25 movement knowing the controls time history, and from

1 this movement, we calculate the associated loads. To
2 run this simulation method, we have used, I would say,
3 two analysis. The first one, of course, is Simulation
4 1. It is done with the flight mechanic module which is
5 the one used by handling quality and which has been
6 presented to you by the first witnesses.

7 For the Simulation 2, we have used a model
8 which is used in the loads analysis for the conditions
9 which are requested to be handled by the requirement,
10 like the wing maneuver, and in that case, the flight
11 mechanic module which is used is the one used for the
12 loads calculation at time of certification and we use
13 the lateral movement coming from these equations and
14 the longitudinal movement is the same as the first one.

15 So, therefore, this comparison we have our
16 two models, especially the one we have used from the
17 time of certification, and the second one is the
18 kinetic ny integration methods where the sideslip is
19 coming from the flight mechanic equations without using
20 any models. This is a summary table. The simulation,
21 flight mechanic movement, the aircraft movement is
22 calculated by the flight mechanic module for landing
23 quality, using the controls movement coming from the
24 DFDR in the post-treatment, like the rudder. It
25 calculates the movement of the aircraft and the

1 sideslip, and with the sideslip and the rudder
2 movement, using loads module, you are able to calculate
3 your loads on the component like the rudder.

4 The second simulation is using the flight
5 mechanic module from the loads calculation aspect and
6 the same loads module for the loads, and we -- this is
7 called full load simulation. It's called -- this
8 process is called also bypass because in this process,
9 we bypass the flight mechanic module from the loads and
10 the one coming from the handling quality. The kinetic
11 continuation methods. The sideslip is calculated by
12 the kinetic approach and the rudder deflection is the
13 same as the other one. The same loads module to
14 calculate the loads. So, in fact, we have three
15 curves.

16 The result is as follows. This is the time
17 axis. The black curve is the rudder movement. The red
18 curve is the kinetic NY integration research which was
19 presented to you yesterday. The blue and green curve
20 are the results of the two simulations using the
21 bypass, I mean the handling quality model for the
22 flight mechanics, and the green one is using the loads
23 flight mechanic module, and you can see that these two
24 simulations give very good fit, as well as to the
25 kinetic integration method in terms of aircraft

1 movement.

2 In terms of loads, the blue and green curve,
3 which are very close, represents the simulations
4 research. This is versus time and the upper part of
5 the rudder bending, and there's a second part, the
6 torsion. Development of the bending against time. Up
7 to this point, we have a good fit between the three
8 calculations and at that time, which is around the time
9 of the vertical tail separation, when you have the
10 simulation, the movement of the aircraft is obtained
11 with the fin still fitted on the aircraft. The loads
12 are also calculated with the fin on the aircraft. With
13 the kinetic integration methods, the movement of the
14 aircraft is already the movement of the aircraft in
15 terms of time with or without fin, and the loads are
16 calculated with an aircraft fitted with a fin because
17 we are not able to do that the other way. So, those
18 loads are if the fin is on the plane. So, up to this
19 point, we have a good fit and here you see a
20 discrepancy, meaning that something had happened, is
21 the reason we can say the fin separation up here most
22 probably in this period of time.

23 MR. MURPHY: Mr. Curbillon, would you just go
24 back one slide there for a second? It looks like your
25 scale -- it just was noted to me, your scale dropped

1 off your torsion graph. Do you have an idea of what
2 those values --

3 MR. CURBILLON: Here?

4 MR. MURPHY: No. Your -- your left-hand
5 scale for your -- for the value of your torque is
6 dropped off.

7 MR. CURBILLON: Oh, sorry. You will see the
8 value on the next charts.

9 MR. MURPHY: Okay.

10 MR. CURBILLON: So here is the movement. The
11 definition in torsion and bending. You start from zero
12 at this point, the first deflection, second deflection,
13 third movement. Here we are at the end of -- at the
14 end of this time. The fourth deflection. We move to
15 the end of the deflection. We go to that direction.
16 The loads move that direction, and when you are at that
17 time, you have the kinetic equation moving like that
18 and the loads increase again for the reason that I
19 explained to you before, and for the simulation due to
20 the movement of the aircraft with the fin in, you have
21 this movement.

22 To answer to your question, this area of the
23 torsion is around 8 -- 6 -- 6 to 7,000 Meter-
24 Decanewtons. The -- you will answer that real value to
25 that later on, and here, we have some differences into

1 this. To have a quick area for the load case selection
2 at the time of rupture, we have defined several
3 conditions. It's not easy to have -- to detect when
4 the fin may have leaved the -- the -- the aircraft.
5 The first one is here, we represent again the time, the
6 lateral-acceleration. The lateral-acceleration, and
7 when you are at that time, you have an abrupt change in
8 the acceleration, and these loads of acceleration looks
9 like the movement coming loose of the fin. So, we take
10 a quick area, which is the maximum acceleration at that
11 time, and if I tried to put this time in line with the
12 Performance Report, it corresponds to the time
13 9:15:58.42. So, I can give you the values later on.
14 And if we take into account the change in slope which
15 happened in terms of the torsion bending curve, we have
16 a slightly different time which is corresponding to the
17 NTSB Performance Report, 9:15:58.3.

18 For the simulation, we take into account the
19 maximum value of the bending moment at root. As a
20 result, you have the kinetic equation. The loads --
21 the change of rupture or what we call the corner
22 bending torsion, which is the case which is named V371,
23 and the second case at the NY, lateral-acceleration
24 maximum, which is called V375, and here we have the results
25 of this simulation using the flight mechanic movement

1 which gives us this maximum value of bending, a case
2 which is called K376. Those numbers are the reference
3 for the loads case we have given to the Stress people.

4 So, with those results, we have, I would say,
5 a range of results coming from different methods,
6 different models, which give us an order of magnitude
7 of, I would say, loads which have been seen by the fin
8 at all those times, and here, you observe values. The
9 bending moment from this point is 158,300 cells in
10 Meter-Decanewtons and so on up to this value which is
11 182,500 Meter Decanewtons with the associated torsion.

12 In order to have, I would say, in this bubble
13 of -- I would say which represented bounding of the
14 loads and from a minimum value to a upper value and if
15 we take into account all these four cases, you can
16 define a mean kinetic value which gives you a value of
17 around -- not around, a value of 169,325 Meter-
18 Decanewtons. So, it gives -- it's a bounding of the
19 cases, knowing that for the kinetic equation which do
20 not use any loads, any model for establishing the
21 sideslip, we have, I would say, these two values which
22 are the 172-182,000 Meter-Decanewtons.

23 So, this gives us the information we have
24 obtained from the loads analysis which have been given
25 to the Structure people for stress and strength

1 analysis.

2 MR. MURPHY: And your numbers, one of those
3 methods obviously corresponds with Mr. O'Callaghan's
4 analysis?

5 MR. CURBILLON: Yes.

6 MR. MURPHY: Okay. Which? Do you know
7 offhand? Is it the NY integration that most --

8 MR. CURBILLON: So, if I -- if I look at the
9 -- the -- Mr. O'Callaghan's report, and if I also look
10 for the -- what is called the loads at bounding, in the
11 report of Mr. O'Callaghan, I can read value of around
12 170,000 Meter-Decanewtons.

13 MR. MURPHY: Okay.

14 MR. CURBILLON: Which is fully in line with
15 the results we presented to you here.

16 MR. MURPHY: Of your four criteria then,
17 which leads to my next question, which one would be at
18 the bang of the four methods chosen?

19 MR. CURBILLON: The one which is at the bang
20 is the one which most probably corresponds to the NY --
21 maximum NY. So, it means the case which is the highest
22 value.

23 MR. MURPHY: Okay. Are these the most
24 current values? Are there going to be any more changes
25 fed to you from the Systems Group, from the simulation,

1 or have all the biases and -- to the best of your
2 knowledge, I understand it's not your area, but are you
3 expecting any more revisions or tweaks to these
4 numbers?

5 MR. CURBILLON: As it has been said, we are
6 continuing some activities to try to refine a little
7 bit more the present results, but in terms of loads,
8 the impact of this refinement will be most probably
9 some very small adjustments and they will not change at
10 all, if we can.

11 MR. MURPHY: Okay. I can see what the four
12 methods we get -- probably the four methods probably
13 answer my next question, but have you ever -- have you
14 done any other independent sensitivity studies, say, of
15 the effect of sideslip or -- or rudder on -- on the net
16 loads? I mean, when you look at these four, you can
17 see the differences, the scatter that's available.

18 MR. CURBILLON: This was one part of the -
19 one of your -- one part of your answer, that it shows
20 that with this approach, you have already a sensitivity
21 to the different cases because the sideslip, for
22 example, slides but not a lot. You can see the
23 sensitivity of the loads analysis, but on top of that,
24 there was, of course, some sensitivity made. Maybe you
25 can comment.

1 MR. KERLIN: But I've made a very short study
2 about the sensitivity of pattern and delta
3 combinations, and more or less this is -- this is
4 confirmed. So, this gives already the answer here.

5 MR. MURPHY: Okay. For 587, going back to
6 the comment, the comment -- the question and then the
7 comment by Mr. Howford regarding static loading or an
8 impulse-type loading, would you agree with Mr.
9 Howford's opinion that it be a static loading for 587?

10 MR. CURBILLON: I agree.

11 MR. MURPHY: And then, I could infer that you
12 feel the structure developed the loads completely?

13 MR. KERLIN: Yes.

14 MR. CURBILLON: Yes.

15 MR. MURPHY: Is there -- along this line of
16 questioning, -- no. That's okay.

17 Have you gone to any other methods, say gone
18 back to your wind tunnel test data or maybe possibly
19 used any of your CFD available to try and just go back
20 and say that we're getting a commonality using some
21 other techniques rather than using our original loads
22 programs?

23 MR. CURBILLON: We have done something, and
24 we may comment.

25 MR. MURPHY: Okay.

1 MR. KERLIN: We have done something, based on
2 the CFD calculations, where we have used the parameter
3 out of these exercise and we have put up several stages
4 of models, and in general, the results of the CFD with
5 the full developed model and some considerations
6 concerning flexibility and -- and so on confirms our --
7 loads results.

8 MR. MURPHY: Okay.

9 MR. KERLIN: We are -- maybe I made -- it's
10 something -- the results differed for the last point
11 about four percent.

12 MR. MURPHY: Okay. Back to the discussion
13 that we've been having regarding Dutch roll, do you
14 feel the response of the aircraft, say, in -- in
15 sideslip is -- is comparable to what would happen
16 during a Dutch roll event?

17 MR. KERLIN: In any case, the Dutch roll is
18 excited here clearly.

19 MR. MURPHY: The Dutch roll is excited here.
20 Okay. Moving on to 903, if you could, please, 903 is
21 summarized in Exhibit R, if you could just for me just
22 summarize the material contained in that exhibit
23 regarding the loads computations for 903?

24 MR. CURBILLON: Would you like to have the
25 slides or not?

1 MR. MURPHY: I --

2 MR. CURBILLON: So, the --

3 MR. MURPHY: You could use the -- what --
4 what slides you feel are pertinent to answer the
5 question.

6 MR. CURBILLON: I would start with - to
7 summarize what we have done. So, this event up here,
8 in May '97, was a stall and with several controls
9 movement, and we have high loads vertical factor and
10 also high loads in the stall factor. During this
11 event, we have some difficulty to get all the necessary
12 information, even if we have, I would say, a DFDR which
13 provide us a lot of parameters coming from the flight.
14 Unfortunately, we have, I would say, a slice of time
15 where we have not recorded all the information due to a
16 unit issue and two additional slices of time where we
17 have no recording at all.

18 But up to the time, we have all the necessary
19 information and all the parameters which are recorded
20 on the DFDR, we can make a loads assessment. To do
21 this load assessment, we used the kinetic schematic
22 approach which is to derive the sideslip by the kinetic
23 equation without any simulation. Here, you can see the
24 versus time as the event is a speed evolution during
25 this event. With this slice of time I was talking

1 about, one, we have not all the information, but still
2 the NY lateral-acceleration recorded. No recording, no
3 recording.

4 This is the vertical G which moved from minus
5 .45 to 8, and this was recorded during this slice of
6 time. The bank angle from minus 75 to 80 degrees. The
7 lateral G loads recorded during this time from minus
8 .75 to minus .2+.5. The rudder deflection during this
9 event with where it is not recorded at all, and when we
10 run the -- the kinetic equations, as it is an
11 integration method, up to the time you have all the
12 information, you are in the range of the assumption
13 which are linked. When you lose some information like
14 geographic altitude, you cannot do the calculation
15 directly. So, what we have done is to simply
16 interpolate by spring curve, so link-link, which links
17 the starting point and the end point, but just for
18 interpolation, and in that case, you lose some
19 information and the quality of your analysis is more --
20 is more and more doubtful, and when you have no
21 parameter at all, you really can question the validity
22 of your results.

23 As a result of the analysis, up to this time
24 here, we have all the necessary information to run the
25 calculation and we have within the assumption the

1 method, and the maximum bending loads is that we have
2 exceeded the ultimate loads at the value which is 1.53.

3 After that, you have some other loads development,
4 here it is higher, but once again, here it is doubtful.

5 What we can do here is more doubtful as well, but for
6 information, it is what we can derive. But really, the
7 quality is really inaccurate, and if we run into the
8 torsion bending, you will recognize the previous design
9 limit and the ultimate envelope for yawing maneuver.
10 The discreet gust limit, the discreet gust limit, and
11 the full-scale test rupture.

12 The development of the loads during the 903
13 event, start from that, here we are at .5 limit loads.
14 We exceed the limit loads here, came back again. Here,
15 we are outside, slightly outside of the ultimate limit
16 loads at 1.53 up to this time. After that, the loads
17 calculation are slightly doubtful because we have not
18 all the information and we continue with this type of
19 movement and we can come back again to that direction
20 later on.

21 MR. MURPHY: For this event then, were the
22 sideslip -- the loads due to sideslip and the loads due
23 to rudder additive as in 587?

24 MR. CURBILLON: Yes.

25 MR. MURPHY: Okay.

1 MR. CURBILLON: But in this event on top of
2 that, we have very large displacement, and we have
3 taken into account some non-linearities versus sideslip
4 and rudder deflection.

5 MR. MURPHY: Okay. I think Mr. O'Callaghan
6 may touch on those. That's included in your -- the
7 loads module then?

8 MR. CURBILLON: Yes.

9 MR. MURPHY: Okay. The in-service events
10 that are described in Exhibit Q, Pages 5 and 6, when --
11 when were these values calculated?

12 MR. CURBILLON: The values calculated in this
13 -- in this table use the same approach as the kinetic
14 NY integration approach, using the DFD data -- DFDR
15 data which are -- which have been made available --
16 which were available within Airbus.

17 MR. MURPHY: Okay. For the '97 event, had
18 you done loads evaluation?

19 MR. CURBILLON: For the?

20 MR. MURPHY: '97 event. Prior to the 587
21 accident, prior to the 587.

22 MR. CURBILLON: At the time of the event, we
23 have made, I would say, not a real calculation but we
24 have made -- based on the different traces, we have
25 made an assessment of the loads level using engineering

1 judgment, taking into account the movement of the
2 aircraft, taking into account the rudder deflections,
3 and it was what we have done at that time.

4 MR. MURPHY: Okay. That's sufficient. Just
5 two final questions then. 587 and 903, did they
6 experience certificated maneuvers?

7 MR. CURBILLON: No.

8 MR. MURPHY: Okay. And then, the loads for
9 587, were they within the design envelope?

10 MR. CURBILLON: No. They are outside.

11 MR. MURPHY: Okay. Madam Chairman, I'd like
12 to allow Mr. O'Callaghan to question the witnesses.

13 MR. O'CALLAGHAN: Thank you, Madam Chairman.

14 Good morning, gentlemen. I just have one
15 question or one area of questioning and that has to do
16 with the validation of the loads module. Yesterday,
17 Mr. Offerman testified that, you know, the FAA -- the
18 regulation authorities go through some pains to have
19 the applicants demonstrate that the methods that they
20 used to calculate loads in fact reflect the performance
21 of the airplane or the loads experienced in flight, and
22 Brian asked -- Mr. Murphy asked a question about --
23 about the CFD that confirms some of your results, and
24 in a slide in your presentation, you had pointed out
25 that the loads module and the calculations come from

1 wind tunnel tests and are validated by other kinds of
2 tests.

3 I was just wondering if you could go into a
4 little bit more detail or -- or just briefly describe
5 the kind of other tests that validate the loads modules
6 and the wind tunnel tests and if any of this data is
7 still available.

8 Thank you.

9 MR. CURBILLON: So, first of all, the basic
10 data for aerodynamic model are coming from wind tunnel.

11 So, therefore, we use wind tunnel test data which is a
12 good support to establish the data to be used for the
13 loads calculation as well in terms of aircraft
14 derivative, component derivatives, and distribution as
15 well, and those distributions have been established
16 from wind tunnel tests pressure measurements and which
17 give us distribution of unit loads or distribution of
18 loads on the vertical tail as a function of the span,
19 the distribution across the cord, and these
20 distributions are used for the loads calculation.

21 Later on, based on that which is, I would
22 say, the basis for experimental data, we also perform
23 some different type of tests and we have performed, for
24 example, to validate the model, the ground vibration
25 test, which validate the dynamic behavior of the

1 aircraft for the discreet wind gust calculation
2 continues to be unsteady.

3 We have also, and this has been made by
4 structure checks, the flexibility of the fin when they
5 are doing their static loading, and later on, in terms
6 of development of the aircraft, we have performed some
7 flight tests to validate the models we use for the
8 loads calculation, and this is the basic which was at
9 the time of certification, and in the frame of the
10 energies of the 587, there was the CFD calculation
11 which has been mentioned by Mr. Kerlin.

12 So, if you want more information on this
13 case, you can ask Mr. Kerlin to explain to you.

14 MR. O'CALLAGHAN: Okay.

15 MR. KERLIN: I would like to make one further
16 sentence, that the considerations for the accident
17 itself is a further confirmation because we couldn't
18 confirm the behavior of the aircraft during this
19 accident very well.

20 MR. O'CALLAGHAN: Okay. Thank you.

21 And the wind tunnel, the ground vibration
22 test and the flight test data that you mentioned, is
23 that still in the archives or available?

24 MR. KERLIN: The results of that are
25 available. Unfortunately, the raw source of the wind

1 tunnel data is -- is no longer available.

2 MR. O'CALLAGHAN: And for the other tests as
3 well, the flight test and the ground vibration tests?

4 MR. CURBILLON: The ground vibration tests
5 are available as were some of the flight tests.

6 MR. O'CALLAGHAN: Okay. So, there is some
7 flight tests available, test data available?

8 MR. KERLIN: Yeah.

9 MR. O'CALLAGHAN: Okay. Thank you.

10 Thank you, both, and thank you, Madam
11 Chairman. I have no further questions.

12 ACTING CHAIRMAN CARMODY: Thank you.

13 Is there anything further from the Technical
14 Panel for the witnesses?

15 (No response)

16 ACTING CHAIRMAN CARMODY: All right. Then I
17 will move to the Parties. I propose the order of FAA,
18 American Air Line Pilots and finishing with Airbus.
19 So, beginning with the FAA, Mr. Donner, any questions?

20 MR. DONNER: Thank you, Madam Chairman. We
21 have no questions.

22 ACTING CHAIRMAN CARMODY: All right.
23 American, Mr. Ahearn, any questions for the witnesses?

24 MR. AHEARN: Yes, Madam Chairman. Thank you,
25 and just a couple topics I'll touch on.

1 Good morning, gentlemen.

2 MR. CURBILLON: Good morning.

3 MR. KERLIN: Good morning.

4 MR. AHEARN: I'm going to start off with some
5 reference to Exhibit 7Q, specifically Page 6.

6 MEMBER BLACK: Is someone going to put that
7 up for us or have we got to find it?

8 MR. AHEARN: I'm going to reference you to --

9 MEMBER BLACK: You spoiled us yesterday.

10 MR. AHEARN: I'm going to reference you to
11 the February 1991 event involving the A310 with a
12 composite tail. This was referred to in testimony
13 yesterday as the Interflug German Airline event
14 involving loss of control. Were you in the audience
15 yesterday?

16 MR. CURBILLON: Yeah.

17 MR. AHEARN: Okay. And -- and in reviewing
18 that event, did you perform loads calculation on the
19 vertical stabilizer at the time of the 1991 event in
20 order to determine, as Exhibit 7Q shows, that the tail
21 exceeded ultimate loads?

22 MR. CURBILLON: I -- I cannot answer because
23 I do not remember exactly what was done at that time.

24 MR. AHEARN: And Mr. Kerlin?

25 MR. KERLIN: I'm also not -- not sure whether

1 we have done that at the time.

2 MR. AHEARN: The calculations on that
3 exhibit, when were they done?

4 MR. CURBILLON: They have been done in early
5 2002.

6 MR. AHEARN: So, -- so, none of those
7 calculations were done until 2002?

8 MR. CURBILLON: There was probably something
9 done at the time of the event, but I was not personally
10 involved at that time.

11 MR. AHEARN: Do you know who would have been
12 involved at that time, and any subsequent witnesses
13 that will come forward, would they have been involved
14 at that time?

15 MR. CURBILLON: I don't know.

16 MR. AHEARN: With the inspection being
17 conducted or the review of the load calculation in
18 2002, did Airbus recommend that this carrier replace
19 the vertical stabilizer since it had been exposed to
20 exceeding ultimate loads?

21 MR. CURBILLON: So, we -- we, as far as that
22 is concerned, we have made the loads analysis and we
23 have provided our results here, and you can see that
24 the level of loads we have achieved is 1.5, a little
25 bit above the ultimate loads, and this plane today is,

1 I would say, the handling of this plane, in fact, there
2 is replacement or not of the fin is not in the domain
3 of the loads analysis. So, therefore, we have -- we
4 provided the information, but I cannot tell you more
5 detail in terms of how this activity is handled in
6 terms of fin or not replacement.

7 MR. AHEARN: Okay. And -- and so, you don't
8 know if it's been recommended to be replaced. Do you
9 know if any of the subsequent witnesses will know?

10 MR. CURBILLON: Maybe the Structure people.

11 MR. AHEARN: Okay. Thank you.

12 I'm going to refer to the same Exhibit 7Q,
13 Page 5. In 1997, there was another event, this time
14 involving the A300-600, and we're referring to that in
15 this hearing as Flight 903, American Flight 903, in
16 which the tail exceeded ultimate load.

17 During the NTSB investigation of Flight 903,
18 did Airbus ever inform the NTSB that it knew of at
19 least one other incident in which an operator
20 introduced large rudder movements in an attempt to
21 recover from loss of control?

22 MR. CURBILLON: Could you repeat your
23 question, please?

24 MR. AHEARN: With the data that this is at
25 least the second event where an airplane exceeded the

1 ultimate load of the -- the aircraft, during the
2 investigation, did Airbus ever advise the NTSB or for
3 that the parties that they knew of at least one other
4 incident in which the operator introduced large rudder
5 movements in an attempt to recover from loss of
6 control?

7 MR. CURBILLON: So, we have -- as far as
8 loads are concerned for the 903, we have informed the
9 internal organization of the loads we have achieved in
10 '97, but we are not involved directly into the -- as
11 far as this was concerned into the NTSB investigation.

12 MR. AHEARN: So, your answer is you don't
13 know if -- if it was --

14 MR. CURBILLON: Yes.

15 MR. AHEARN: Okay. It's my understanding
16 that you twice calculated the loads incurred in 903.
17 Were the results in the 2002 loads calculation
18 different from the 1997 loads calculation?

19 MR. KERLIN: First of all, in 1997, there has
20 been loads assessment, no direct loads calculation, but
21 already this assessment shows or says we have most
22 probably reached loads level which is above ultimate,
23 and this was confirmed by the 2002 calculation.

24 MR. AHEARN: Okay. And can you explain with
25 an airplane exceeding ultimate loads or an assessment

1 of an airplane exceeding ultimate loads why a loads
2 calculation was not conducted at the time?

3 MR. CURBILLON: We can answer to that. At
4 the time when we have made this assessment, which was
5 based on the information available, we have informed
6 the, I would say, internal information of Airbus that
7 we were aware of the ultimate loads, and the
8 appropriate actions in terms of inspection have been
9 launched within the Airbus organization. So, it means
10 we, Loads Department, we have the appropriate
11 information for both parties to run an inspection
12 because we have achieved very high loads, and these
13 inspections have been launched, and later on, when we
14 have the results which was stated and explained that
15 there was no significant findings, especially on the
16 fin. At that time, the loads activity was, I would
17 say, internal.

18 MR. AHEARN: So, at the time -- once again,
19 even though you had knowledge that an airplane exceeded
20 ultimate loads, you only conducted an assessment and
21 you didn't think it was appropriate to complete an
22 analysis?

23 MR. CURBILLON: That's not exactly what I
24 said. I said we have warned that we have a level of
25 ultimate loads which has been achieved and this has

1 been known and the companion was also informed to
2 everybody, and if you came back to the command of
3 learning, the calculation which has been performed in
4 2002 does not change the conclusion of what we have
5 said in 2000 in '97, and you have to remember, also,
6 that in the DFDR, we have in bracket some missing
7 information in the recording of the data which cannot
8 alone to perform a loads calculation in very, very
9 detailed form for an overall set of the event, but any
10 -- what we have done in 2002 confirm the assessment of
11 '97. We learned -- have obtained more results if we
12 have had more detailed calculation at that time.

13 MR. AHEARN: Okay. And then, I'm going to
14 refer you back to the 1991 event. Did you have the
15 same problem with the DFDR data in the -- off of the
16 1991 airplane as well?

17 MR. CURBILLON: No.

18 MR. AHEARN: And can you tell me why there's
19 a difference?

20 MR. CURBILLON: On what?

21 MR. AHEARN: The DF -- so, the DFDR data on
22 the 1991 airplane is not filtered?

23 MR. CURBILLON: It's not a question of
24 filtering. You know, in the '97 event, there was some
25 time for the recording, and in some slice of time, for

1 example, we have no recording at all.

2 MR. AHEARN: Okay. So, it's the blanking
3 issue that occurred?

4 MR. CURBILLON: Yes.

5 MR. AHEARN: Okay. Okay. I'm -- I'm with
6 you. Thank you.

7 I'm going to refer you to an Exhibit 7LL, and
8 if you need to bring it up, that's okay. You can. I'm
9 going to read it to you. It's Pages 3 and Pages 4, and
10 then this -- it is a document that reads, in the second
11 sentence, "They have clear concerns on the overall rear
12 part of the aircraft, which could have encountered
13 loads higher than the design limit loads."

14 On Page 4, in the paragraph that stars with
15 "Meanwhile, the study confirms high load factors, both
16 longitudinal and lateral aspects." It appears in the
17 following sentence that for some areas of the airplane,
18 limit design loads have been exceeded and for some
19 others, such as the rear fuselage fin and empennage,
20 and I know you already testified that you handed this
21 off as an internal document to Airbus, but do you know
22 why this information was never given to the NTSB nor
23 the parties at the time of the event?

24 MR. CURBILLON: So, first of all, I cannot
25 agree with you on one thing. Myself, I was not

1 directly involved into the NTSB investigation at that
2 time, but those information were known internally, and
3 I cannot agree on the fact that you say they have never
4 been. Maybe this took pure document as maybe not
5 provided, but I don't know, but the information that we
6 have achieved, the high level of loads, was known.

7 MR. AHEARN: Okay. Well, this information,
8 frankly, as a party to that event, sir, this
9 information was just discovered this year. So, I don't
10 know that anybody -- that this information was ever
11 discovered, but I'll move on.

12 MR. CURBILLON: But this information showed
13 one thing, that we have reviewed the -- the facts.

14 MR. AHEARN: Yes. You -- you reviewed the
15 facts. I don't know that it was shared, but I'll move
16 on to my other questions.

17 Let me just refer to again by 1997, given the
18 fact that the A310 operator, A300 or A310 operator may
19 have exceeded ultimate loads based upon rudder
20 reversals, passing that information on, did you pass
21 that on to the appropriate flight department so that
22 this information could be disseminated to all operators
23 via technical publication?

24 MR. CURBILLON: The -- after the event of
25 903, there was communication on the rudder movement.

1 I'm sure you know that. The first time, there was the
2 recommendation which was given by the common letter
3 from the foreign manufacturers and the FAA. There was
4 also the submission letter from Airbus, and I would
5 like maybe to add something.

6 All those events are events where the
7 aircraft have been in very unusual conditions, and
8 Airbus as well as also under different actions to
9 minimize the risk to be again in this type of situation
10 and including information like the one I have described
11 to you before.

12 MR. AHEARN: Okay. I would -- I won't get
13 into the letter issue because I think we've already
14 been through that a number of times.

15 MR. CURBILLON: Yes, it has been already
16 discussed.

17 MR. AHEARN: But that -- that did not refer
18 to the 903 event, and in fact, again it did not result
19 in a formal publication, such as a change to the --

20 MR. CURBILLON: There was some formal
21 presentation. The -- I cannot agree with that. There
22 was some formal information. The letter which was sent
23 to -- to you was a formal information. The submission
24 was a formal information.

25 MR. AHEARN: Okay.

1 MR. CURBILLON: Just a fact. Factually, it
2 is the case.

3 MR. AHEARN: I'm -- I'm not going to go on
4 that line of questioning, Madam Chairman, because I
5 think that we've already resolved that issue, that --

6 MR. CURBILLON: Okay.

7 MR. AHEARN: -- there was no formal FCOM,
8 that we have plenty of letters back and forth, but I'll
9 move on to other questions.

10 I'm referring to 7Q once again, and I'll note
11 that on Page 2, there are a number of high load events
12 involving crew rudder inputs. Do you know in how many
13 of these cases you see the crew taking the rudder to
14 the stops? I'm sorry. Page 5 and 6. It's Exhibit 7Q,
15 Page 5 and 6.

16 MR. CURBILLON: At minimum, the two event
17 where the aircraft has experienced extreme conditions
18 following the stall and during the recovery, but for
19 the other, I do not from memory see a real -- such
20 severe movement than on the two events we are talking
21 about.

22 MR. AHEARN: Okay. If you -- if you had that
23 -- have that data on all these events, if you could
24 provide that to the parties, that would be appreciated.

25 MR. CURBILLON: I see no problem with that.

1 MR. AHEARN: Okay. Thank you.

2 Moving on, I'm going to refer back to some
3 questions that we talked earlier in the -- in the
4 hearing on, and I'll ask you regarding the -- the A300.

5 If the A300 rudder was hinge moment, if it had hinge
6 moment limiter, would this reduce the sideslip and the
7 loads on the fin?

8 MR. CURBILLON: By -- by definition, yes. If
9 you limit the rudder deflection, you will reduce the
10 loads on the fin.

11 MR. AHEARN: Okay. And then, a follow-on
12 question to that. If -- if the directional control
13 system had been designed so that the yaw damper inputs
14 opposed the rudder inputs or opposite the rudder
15 inputs, excuse me, could not have been overridden by
16 additional pilot pedal input, would this not have also
17 reduced the sideslip and/or the loads on the fin?

18 MR. CURBILLON: In fact, the evidence is that
19 way. We have run the calculation without preparing
20 calculations. So, therefore, we have taken this kind
21 of conservative way to do our calculations.

22 MR. AHEARN: I'm not certain I understand the
23 answer to your question. Let me -- let me repeat the
24 question again to see if --

25 MR. CURBILLON: That would be the case, yes.

1 MR. AHEARN: Okay.

2 MR. CURBILLON: Thank you.

3 MR. AHEARN: If the directional control
4 system had been designed so that the yaw damper inputs
5 opposite pilot inputs could not have been overridden by
6 additional pilot pedal input, would this not have in
7 fact reduced the sideslip and therefore reduce the load
8 on the fin?

9 In other words, if you have a yaw damper that
10 can't be overridden, won't that reduce the load?

11 MR. CURBILLON: As far as the loads, the
12 design loads is concerned, my answer is the same as
13 previously. We have run the calculation without, so we
14 do not take any benefit for the number, and we in fact
15 -- it is a form of conservatism to the loads
16 calculation for the design, and in any case, when we
17 are doing the loads calculation, we use the system as
18 it is normal.

19 MR. AHEARN: Okay. I'll just try it one more
20 time because you're answering the question as it refers
21 to the 587 calculation, and I'm not asking about the
22 587 calculation. I'm sorry. Your -- your -- I think
23 what you're doing is you're answering the question
24 about certification and what I'm asking is about the
25 587 calculations that you did.

1 MR. CURBILLON: In that case, it's
2 speculation, you know, and we run the calculation for
3 the 587 as it was.

4 MR. AHEARN: Okay. Let me move on then. How
5 many different load calculations did you do on the 587
6 -- on Flight 587?

7 MR. CURBILLON: How many type of calculation?

8 MR. AHEARN: Yeah. Yes.

9 MR. CURBILLON: In fact, the calculation is
10 different what we put behind the types. If I
11 understand types as which kind of calculation we have
12 performed, it is one we have presented to you. In
13 fact, we have four calculations. For these four
14 calculations, we have two types of approach. One is
15 simulation, one is kinetic NY integration. For the
16 simulation, we used two different models, and for the
17 kinetic equations, we used two criterias; one at the
18 time of discontinuity of the bending and torsion, the
19 second, at the maximum lateral acceleration, which
20 represent to us, I would say, a set of different
21 approaches, a set of different criteria, which give us
22 continuance and bound the level of loads we have
23 obtained from our calculations.

24 MR. AHEARN: Okay. And -- and all four
25 calculations have been provided to the parties, sir?

1 MR. CURBILLON: Yes. It is as they are in
2 the exhibits I have presented before.

3 MR. AHEARN: Okay. Thank you.

4 I want to move on to a different topic for a
5 moment. You talked about the 310 versus the 600, but
6 I'm going to take you back a little bit further in the
7 evolution of the airplane.

8 Can you tell me if the B2B4 or the 600 had a
9 higher load limit? Which -- which design had a higher
10 load limit?

11 MR. CURBILLON: So, it depends of the -- of
12 the -- in terms of which parameter, because, you know,
13 there is a lot of parameter on the aircraft. In terms
14 of which -- which component?

15 MR. AHEARN: The vertical. I'm sorry. The
16 vertical stabilizer.

17 MR. CURBILLON: So, straight answer, the
18 highest load is A310-300 but slightly above the A300-
19 600.

20 MR. AHEARN: And how about the B2B4?

21 MR. CURBILLON: B2B4 is difficult to answer
22 because the B2B4 was a different aircraft with
23 different design weights with different lengths as well
24 and different engine as well. So, therefore, some time
25 or so, the requirements are not exactly the same. Even

1 for the B2B4, it was the same as the 600, more or less.

2 But again, the -- the fin which is common on
3 both planes is the one which is fitted on the 310-300
4 and the A300-600R, and the 310 loads are slightly
5 higher than the 600R. From memory, I cannot refer
6 about loads on the B2B4, but they were probably lower,
7 but for different -- because the aircraft are different
8 in terms of weight, CG and inertia.

9 MR. AHEARN: Okay. But -- but you -- I don't
10 expect you to answer the question from memory, but you
11 would have that data. Would you provide that data to
12 the parties as well?

13 MR. CURBILLON: Yes, without any problem.

14 MR. AHEARN: Very good. Thank you.

15 One final topic, Madam Chairman, and I'll
16 move on. The design of the vertical stabilizer
17 apparently focuses the loads predominantly on the aft
18 lug. Can you discuss the -- the design loads on the
19 vertical stabilizer specifically as it relates --
20 obviously in your area of expertise with regard to
21 loads?

22 MR. CURBILLON: So, for this purpose, we
23 produce the overall all loads, what we call external
24 loads. So, it means the shear, bending and torque
25 along the span for different sections of the fin. We

1 are not looking in detail because we cannot accept, if
2 we have the criteria selection, the particular loads on
3 the attachment because if they are internal loads and
4 those loads are calculated by the Structure people
5 using their own model. So, we produce the external
6 loads. They calculate internal loads.

7 MR. AHEARN: Okay. Maybe that's a better
8 question for Mr. Winkler and I'll defer that question
9 till later.

10 Madam Chairman, that's all the questions I
11 have. Thank you.

12 ACTING CHAIRMAN CARMODY: Thank you.

13 Moving now to Allied Pilots, Captain Pitts,
14 please.

15 CAPT. PITTS: Good morning, Madam Chairman.
16 Good morning, gentlemen.

17 MR. CURBILLON: Good morning.

18 CAPT. PITTS: In your loads review, has
19 Airbus looked at aircraft types, other than the A310,
20 the A300-600, for instances in which the aircraft was
21 exposed to loads that exceeded limit or ultimate limit?

22 MR. CURBILLON: I'm not sure I understood
23 your question.

24 CAPT. PITTS: Your research on -- you -- you
25 shared with us that you conducted a loads review. My

1 question is, is in that review, has Airbus as a company
2 taken a look at other aircraft types, other than the
3 A310 or the A300-600, where the aircraft was exposed to
4 loads that exceeded limit or ultimate limit loads?

5 MR. CURBILLON: In this particular story, we
6 looked basically on the A300 and the A310, but we are
7 also looking for the other aircraft as well.

8 CAPT. PITTS: Were there any found? Any
9 other aircraft designs found that -- that had
10 experiences that exceeded load limit or ultimate limit
11 as they were designed to?

12 MR. CURBILLON: Maybe one.

13 CAPT. PITTS: Could you share that model with
14 us?

15 MR. CURBILLON: No. It's because it's part
16 of the discussion we have.

17 CAPT. PITTS: I see. All right, sir. I'm
18 going to refer to Exhibit 2-N, Page 6, if you want to
19 bring that up, and I'll go ahead and ask the question
20 because the question doesn't require that it be
21 present.

22 My question, gentlemen --

23 MR. CURBILLON: What was the page?

24 CAPT. PITTS: Page 6.

25 MR. KERLIN: What -- what was the reference?

1 2-N?

2 CAPT. PITTS: Exhibit 2-N, Page 6.

3 MR. CLARK: That's not on one of their --
4 it's not on their list of exhibits.

5 CAPT. PITTS: Okay. As I said, it's not
6 necessary for them to answer the question. I just
7 thought it might help them.

8 Do Airbus load engineers review all of the
9 flight crew operating manual procedures before they are
10 given to the operators?

11 MR. CURBILLON: We were not directly -- I was
12 not directly involved into the FCOM.

13 CAPT. PITTS: So, if -- if a procedure that
14 may impose a load on the aircraft by the operator, by
15 his operating technique, were developed in the training
16 or the Flight Department, it would not be moved through
17 the Engineering Department and reviewed for loads?

18 MR. CURBILLON: In case of, it could be.

19 CAPT. PITTS: Okay, sir.

20 MR. CURBILLON: It's part of the internal
21 organization of the -- of the company.

22 CAPT. PITTS: In reference to the procedure
23 that directs operators to use alternating sideslips
24 that was referenced in 2-N, Page 6, did the Airbus
25 Loads Group calculate the loads that that maneuver

1 would place on the vertical stabilizer if performed at
2 B Max?

3 MR. KERLIN: As far as I know, not.

4 MR. CURBILLON: We have answered.

5 CAPT. PITTS: I'm sorry. I didn't hear your
6 answer, sir.

7 MR. CURBILLON: Same answer.

8 CAPT. PITTS: Same answer. Very well. Since
9 it was not reviewed, you may not be able to answer this
10 question. I'm just curious. What assumptions
11 regarding rate and amount of rudder input might have
12 been assumed in that operator's instruction?

13 MR. CURBILLON: Once again, we are not the
14 experts to talk about the FCOM and to provide you the
15 information you asked to us.

16 MR. KERLIN: But I think one former witness
17 said that it is more or less a stabilized condition.
18 This stabilized condition is covered by the
19 certification requirement calculation.

20 CAPT. PITTS: Okay.

21 MR. CURBILLON: The reason why this -- this
22 action was, I would say, handled like that.

23 CAPT. PITTS: All right. Well, you moved me
24 into an area I was going to get to later, but I'll do
25 it now. In your presentation, you referred to FAR

1 25.351, and I believe your Slide 22 in your
2 presentation speaks to yaw maneuvers as covered in the
3 certification. Do you want to bring that up or you
4 want to just refer to it from memory?

5 MR. CURBILLON: This one?

6 CAPT. PITTS: Yes, sir, that one'll do.

7 MR. CURBILLON: Okay.

8 CAPT. PITTS: Now, the FAR speaks to the
9 rudder input as suddenly displaced, and it sounds as if
10 from your description that we might be stumbling over
11 the definition of suddenly. In the testimony from the
12 test pilots, we heard them speak to it being slow and
13 controlled and you mentioned stabilized.

14 Can you help us understand what philosophy is
15 used or what interpretation is used in reference to
16 this FAR requirement and the need to be able to be
17 suddenly displaced with reference to your design?

18 MR. CURBILLON: I'm not sure I understand
19 completely your question.

20 CAPT. PITTS: Well, what is the rate of
21 rudder deflection input on that -- on that top graph,
22 sir?

23 MR. CURBILLON: The rate -- the rate for the
24 -- for the design calculation uses maximum rate as it
25 has been described by the witness on the first day.

1 So, it means we use a maximum performance of the control
2 surface which is something like 16 degrees per second.

3 CAPT. PITTS: You use a full --

4 MR. CURBILLON: We -- we have to know that
5 for the design, we use, as it has been also explained
6 yesterday by the FAA witnesses, we use, I would say,
7 conditions which are defined, and we use those
8 conditions and sometimes it's difficult to relate,
9 strictly speaking, those conditions to the operational
10 instruction.

11 CAPT. PITTS: So, in relating those
12 conditions to this operational instruction given to
13 pilots, what rate would have been considered
14 appropriate there?

15 MR. CURBILLON: So, I -- I repeat again. For
16 the design conditions, we use, what I would say,
17 conditions which are -- I would not say are in the
18 book, which are conditions that are defined by the
19 requirements. So, we use these design requirements as
20 a maximum rate, and we design for that.

21 CAPT. PITTS: Would it be reasonable then to
22 expect Airbus to calculate this maneuver as described
23 in the operating manual to have been reviewed at
24 different rates and inputs?

25 MR. CURBILLON: You can -- you can make any

1 calculation you -- which is needed, but again, the --
2 as far as loads is concerned, when we design the
3 aircraft, we design for a set of conditions which are
4 envelope, and we are doing it that way.

5 MR. KERLIN: And I mean, the application of
6 the rudder in this sense is the most severe one. If
7 you push the rudder very, very slowly, you will
8 directly enter into the steady sideslip which has no
9 over swing as we see it here in these pictures.

10 CAPT. PITTS: All right, sir. I think you
11 answered the question.

12 Did Airbus consider that a pilot responding
13 to an engine out may apply rudder in the wrong
14 direction followed by a corrective input in the proper
15 direction when you reviewed the design for loads?

16 MR. CURBILLON: In review the design for
17 loads, we -- we followed also as well the type which is
18 in the requirements.

19 CAPT. PITTS: I'm sorry, sir. I didn't catch
20 your first part of your answer. Was it that you just
21 -- just met the design to the requirements? All right,
22 Sir.

23 MR. CURBILLON: Not just. We made the
24 requirements.

25 CAPT. PITTS: Yes, sir. Referring to your

1 Slide 17, just a little bit further explanation, if you
2 would, please, and I'll wait for that to come up.

3 ACTING CHAIRMAN CARMODY: Is that 17 from his
4 presentation?

5 CAPT. PITTS: Yes, ma'am.

6 ACTING CHAIRMAN CARMODY: All right. Thanks.

7 CAPT. PITTS: In terms of gust during the yaw
8 maneuver, is it additive? Would the yaw maneuver and
9 you have a load limit with a gust value of 1.0, would
10 the yawing maneuver be additive to that or is it
11 exclusive of that requirement?

12 MR. CURBILLON: It's not additive for the
13 simple reason, the requirement asks us to run the
14 calculation for serious condition for each individual
15 type of conditions. So, we run the gust calculation
16 with a high severity of the level of the intensity of
17 the gust. We run the yawing maneuver, but we are not
18 combining them.

19 CAPT. PITTS: Are you gentlemen aware of any
20 provision of the FARs or the JARs that prohibit anyone
21 from performing the rudder reversal at max sideslip and
22 incorporating that into their design?

23 MR. CURBILLON: No. Because we follow the
24 requirement as well.

25 CAPT. PITTS: One final question. Now that

1 we have several load cases that have been brought to
2 our attention which exceeded the ultimate load design
3 of the aircraft, one of which was catastrophic, and
4 then the conditions also including such things -- such
5 phenomena as Dutch roll, doublets, sideslip with
6 control, reversal inputs, are there any other loads
7 issues that we, the operators, should be aware of that
8 we could possibly infringe upon in -- in the operation
9 of this aircraft?

10 MR. CURBILLON: Not to my knowledge.

11 CAPT. PITTS: Thank you, sir.

12 I have no further questions.

13 ACTING CHAIRMAN CARMODY: Thank you, Captain
14 Pitts.

15 Before we go on to Airbus, Mr. Ahearn, in
16 your questioning, you asked the witness for a number of
17 documents which he agreed to furnish. Could we have a
18 list of those just to be sure they get properly
19 introduced into the process at your convenience?

20 MR. AHEARN: Yes, ma'am.

21 ACTING CHAIRMAN CARMODY: All right. Thank
22 you.

23 Moving to Airbus, Dr. Lauber.

24 DR. LAUBER: Thank you, Madam Chairman.

25 Mr. Curbillon, you were asked a couple of

1 questions regarding the Interflug airplane which was
2 one of the high-load cases identified subsequent to
3 587. Do you know if, in the inspections, the ultrasonic
4 inspections that were done as a result of the review,
5 were there any findings from those inspections?

6 MR. KERLIN: There was -- following the
7 inspection of this aircraft, from my knowledge, there
8 was no finding at all.

9 DR. LAUBER: Okay. Thank you.

10 Mr. Ahearn asked you a couple of questions
11 with regard to Exhibit 7LL, specifically Page 4. He
12 read to you from Paragraph 3. Could you -- could you
13 describe for us what Paragraph 1 and Paragraph 3 says
14 in general terms? Just summarize what's indicated
15 there.

16 MR. CURBILLON: So, the first one says as the
17 aircraft has experienced severe case, especially as he
18 has exceeded the criteria which are described in the
19 AMM chapter given there, there was, I would say, an
20 automatic triggering of the necessary inspection,
21 necessary action, whatever they are, when you exceed
22 this -- these values, and for example, in the AMM, you
23 have a minimum and then you have the case for the
24 vertical loads factor, much as in accidents, of such
25 value. You have to run some inspections in any case.

1 DR. LAUBER: So, both paragraphs are
2 basically recommending inspections, --

3 MR. CURBILLON: Yes, and --

4 MR. DONNER: -- based on those findings?

5 MR. CURBILLON: Yes. The second one
6 highlight again this fact, but the first one was a
7 warning and we have to inspect in any case. The second
8 one is to reinforce the request for inspection
9 according to the engineering and the investigation made
10 at that time in terms of type of maneuver performed, in
11 terms of loads estimated and assessed.

12 DR. LAUBER: Okay. And this was an internal
13 e-mail that was sent to Jean Daney. Who is Jean Daney?

14 MR. CURBILLON: Jean Daney is the one people
15 working in the Flight Safety organization.

16 DR. LAUBER: And in the upper right-hand
17 corner, what's the date and time indicated on this e-
18 mail?

19 MR. CURBILLON: The date is the 19th of June
20 '97.

21 DR. LAUBER: Would you turn to Page 17 of the
22 same exhibit, please?

23 MR. CURBILLON: 17.

24 DR. LAUBER: Yes, that's the one. Would you,
25 first of all, note the time and date in the upper

1 right-hand corner?

2 MR. CURBILLON: The time and date is June
3 19th, 1997, at 8:29 p.m.

4 DR. LAUBER: About two hours after the one --

5 MR. CURBILLON: Yes.

6 DR. LAUBER: -- we just looked at, and this
7 is an e-mail to whom?

8 MR. CURBILLON: It is an e-mail from the
9 Product report to Mr. Zepf, Airframe Systems, which is
10 American Airlines.

11 DR. LAUBER: It went directly to Mr. Zepf,
12 who is at Tulsa for American Airlines?

13 MR. CURBILLON: I think so.

14 DR. LAUBER: And what does the e-mail say?

15 MR. CURBILLON: The e-mail says that, first
16 of all, to the analysis of the DFDR. "The Airbus
17 industry confirms that summary of the aircraft had
18 sustained very high loads in particular of the aft part
19 of the aircraft, and these loads require the aircraft
20 to be deeply inspected after the event."

21 DR. LAUBER: Okay. Thank you, Mr. Curbillon.

22 The dates on these were 19 June. The event
23 happened on the 12th of May.

24 MR. CURBILLON: Yes.

25 DR. LAUBER: Do you know why it was so long

1 between the time of the event and the -- the
2 notification or the analysis?

3 MR. CURBILLON: From my knowledge, we had
4 been informed first of the event and which was
5 considered an event in turbulence, and we were not able
6 -- so, and based on that, which was only accelerations
7 and description by word, we have run the first loads,
8 preliminary advanced information, and we had expected
9 high loads and therefore we have requested to have the
10 more information to substantiate and to support, even
11 if it is an assessment, to get more information to
12 support our loads view, and for that, we needed at
13 minimum some information on the DFDR, even if it is
14 only traces, we need that to better indicate because
15 when you encounter turbulence, you have seen this type
16 of acceleration, can one use what you may have seen
17 high loads, but to have a little bit more information
18 to support the need for inspection of complementary
19 inspection on the basic one. You will need more
20 information at minimum of the DFDR.

21 DR. LAUBER: Would you turn to Page 5,
22 please, of the same exhibit?

23 MR. CURBILLON: Which is on the 15 of May
24 '97.

25 DR. LAUBER: Three days after the event, and

1 it is what? A letter from or an e-mail from whom?

2 MR. CURBILLON: It is an e-mail from our
3 representative in Tulsa to Mr. Yves Benoist, who is in
4 charge of the Site Safety Airbus industry.

5 DR. LAUBER: And would you read, please, the
6 first two paragraphs of this?

7 MR. CURBILLON: And this -- the first
8 paragraph says, "American Airlines Flight Safety has
9 informed me that they will not give me the DFDR from
10 the subject incident. Further, American Airlines
11 Flight Safety informed me that they will probably never
12 again release a DFDR to Airbus."

13 The second paragraph, "The reason is
14 apparently Airbus and American Airlines are involved in
15 a lawsuit over a previous turbulence incident.
16 Apparently the Airbus lawyers are using the data from
17 the DFDR from the previous incident against American
18 Airlines. Therefore, American Airlines will not
19 subject themselves to possible incrimination again."

20 DR. LAUBER: Now, just one more thing from
21 this. Would you read the second-from-last paragraph,
22 please?

23 MR. CURBILLON: The last one?

24 DR. LAUBER: Second from last, beginning
25 "Further, at this time".

1 MR. CURBILLON: "Further, at this time, no
2 one within American Airlines will ever discuss the
3 incident with me. American Airlines Flight Safety will
4 not even return my calls regarding the incident."

5 DR. LAUBER: Okay. Thank you.

6 Mr. Curbillon, would you put on from your
7 testimony Slide 26? That's the one that shows the
8 dynamic build-up of loads and sideslip.

9 Just actually a couple of questions on this.
10 If you'd take any point in -- if you take the Beta
11 build-up, the upper chart, the upper plot on this, take
12 any point in there and tell us from a loads point of
13 view what would have been different had at that given
14 point the pilot simply released the rudder pedals to
15 neutral?

16 MR. CURBILLON: If the pilot released the
17 pedal to neutral, he will let the aircraft to come back
18 to its zero sideslip condition due to the natural
19 stability of the aircraft, and in that case, it will,
20 as it has been explained earlier during the
21 presentation and following a question from Mr. Murphy,
22 the loads will be lower, and there would be a slight --
23 they would be lower.

24 DR. LAUBER: Would they reach ultimate or
25 limit loads? It depends on when, I guess.

1 MR. CURBILLON: It depends on when. If, for
2 example, you release the loads, for example, at the
3 last case here up to zero, most probably the loads will
4 not achieve the levels they have achieved taking into
5 account the fifth reversal and probably remain but not
6 at the level which has been achieved.

7 DR. LAUBER: And I'm sorry, I missed it.
8 Which -- which point were you talking about
9 hypothetical release or return?

10 MR. CURBILLON: In particular, if instead to
11 have this full fifth reversal, we stop the -- the
12 release at zero at that time. The loads at that time
13 would most probably be lower of the ultimate.

14 DR. LAUBER: Okay. All right. Let's --
15 let's assume a little bit different situation. Let's
16 assume that the fin did not separate from the airplane
17 when it did. What would have happened to the build-up
18 of Beta and subsequent loads, assuming that it stayed
19 intact?

20 MR. CURBILLON: If we continue like
21 that and we made a 6-1, we will significantly again
22 increase the aircraft movement and the sideslip will
23 continue to increase and the loads will continue to
24 increase and again significantly above the level you
25 have achieved at the fifth return to the 6-1,

1 significant increase again.

2 DR. LAUBER: One final question, Mr.
3 Curbillon. Mr. Ahearn asked you a couple of questions
4 about limiting devices, such as hinge moment limiters
5 and different yaw damper design, and asked about the
6 effects on loads from those devices.

7 Would any of those devices have made any
8 difference with regard to the dynamic build-up of Beta
9 due to cyclic rudder input that excites the Dutch roll
10 of the airplane?

11 MR. CURBILLON: If -- if you have rudder
12 movement like that, it would not react differently.

13 DR. LAUBER: It would continue to build?

14 MR. CURBILLON: Yeah. It will continue to
15 build in any case because for the simple reason, if you
16 excite, so you have a cyclic movement and this cyclic
17 movement on top of the reversal is also at a frequency
18 which is close to the Dutch roll, you have -- even
19 though the Dutch roll is stable, you have a large
20 increase of the response of the system, and if you lose
21 the time here for the last rudder movement here, you
22 have a time which is extremely close to the time of
23 Dutch roll case which is from between, for example,
24 this type of douslet this one. You have a frequency
25 which is very close to the frequency of the Dutch roll.

1 DR. LAUBER: Okay. Thank you, Mr. Curbillon,
2 and just one final thing. Are you aware that as a
3 result of the submission that Airbus made to the NTSB
4 during the 903 investigation, that the loads issues
5 were discussed in that submission? Do you know if they
6 were or not?

7 MR. CURBILLON: The submission? I think that
8 there is a part where there was some information
9 related, but I'm sure there are paragraphs which is the
10 loads part is part of that.

11 DR. LAUBER: Thank you.

12 No further questions, Madam Chairman.

13 ACTING CHAIRMAN CARMODY: Thank you.

14 Moving on to the Board, I had one question,
15 and I may have misunderstood your answer earlier when
16 Captain Pitts was questioning you. I think he asked if
17 you had done any load calculations with respect to
18 opposite rudder inputs from the pilot, and I didn't
19 quite hear what you said, if that was the question.

20 MR. CURBILLON: At the time of certificate,
21 when we -- when we designed the aircraft, we do not do
22 it, but in terms of internal policy, we sometimes check
23 the specific case if we have which kind of level we can
24 achieve.

25 ACTING CHAIRMAN CARMODY: When you're

1 designing the aircraft, the tests you -- the
2 evaluations then are based on rudder input in one
3 direction and return to --

4 MR. CURBILLON: Neutral.

5 ACTING CHAIRMAN CARMODY: -- neutral?

6 MR. CURBILLON: Yeah.

7 ACTING CHAIRMAN CARMODY: So, this is --

8 MR. CURBILLON: We design -- we design
9 against your requirements.

10 ACTING CHAIRMAN CARMODY: Hm-hmm. Member
11 Hammerschmidt, any questions?

12 MEMBER HAMMERSCHMIDT: I would like to thank
13 these two witnesses for their very informative
14 presentations this morning, and I have no questions
15 loaded or otherwise.

16 ACTING CHAIRMAN CARMODY: How about Member
17 Goglia for loaded questions? Member Black?

18 MEMBER BLACK: Just a comment. I looked
19 through this material that was in -- that ultimately
20 became 7LL in preparation for this and was somewhat
21 concerned about the flow of information back and forth,
22 both immediately after 903 and then after we started to
23 look at it again after 587, and I would encourage staff
24 to try to ultimately look at a chronology, so that this
25 can be somehow absorbed in the final report, so that --

1 I guess it's sort of what did you know and when did you
2 know it, and I think it's important to the Board and to
3 all of the parties to have that documented accurately
4 in the process of this investigation.

5 I have no questions.

6 MR. CLARK: We agree, and we've already
7 started that. It does raise one issue that Captain
8 Ahearn's raised about the recommendation for
9 inspections.

10 Captain Ahearn, do you know if those
11 inspections were accomplished?

12 MR. AHEARN: Mr. Clark, yes. I appreciate
13 the promotion to captain, but I don't know --

14 MR. CLARK: Oh, sorry. Mr. Ahearn.

15 MR. AHEARN: My colleagues might take issue
16 with that, but yes, those inspections were
17 accomplished, and in fact, the results were given to --
18 to Airbus and the parties, sir.

19 MR. CLARK: Have they been provided to us?

20 MEMBER BLACK: John, they're in LL.

21 MR. CLARK: The results of those?

22 MEMBER BLACK: They went through the items in
23 the maintenance manual about what they did, and I think
24 Airbus then responded back once with some other things
25 they wanted them to look at, and they apparently did

1 it. Unfortunately, this occurred considerably after
2 the accident, and I believe the airplane was flying the
3 entire time, was it not?

4 MR. AHEARN: It was, sir. It flew for five
5 years.

6 ACTING CHAIRMAN CARMODY: You can see we have
7 a board member that reads everything, Member Black. I
8 agree that it's important to get the information on
9 what and when. I don't want this hearing to become the
10 forum for finding out who knew what when because we --
11 we need to move forward, but I think that's an
12 important point.

13 Are there anything else from the Technical
14 Panel?

15 (No response)

16 ACTING CHAIRMAN CARMODY: Any of the parties?
17 Mr. Ahearn?

18 MR. AHEARN: Two points. One is from a
19 clarification. I noted when Dr. Lauber was raising the
20 issue about the data, it referred to high loads, and I
21 don't know that people would interpret in the industry
22 or even somebody reading these documents would
23 understand the difference between high loads and
24 exceeding design loads which was part of -- or ultimate
25 loads which was part of the original documentation, and

1 as you look for that exchange of information, I would
2 encourage the Board to look and see if in fact there
3 was any documentation regarding exceedance of ultimate
4 loads.

5 One other item. It -- Mr. Lauber read into
6 some documents that relate to DFDR data from American.

7 Frankly, I have a hard time understanding how it's
8 relevant to this investigation, but since it's in, I'd
9 like to introduce an exhibit. It's an internal
10 document from Airbus that directly addresses some of
11 those concerns, and it reads in part, --

12 ACTING CHAIRMAN CARMODY: Well, let's have a
13 look at it and then we can make an evaluation. You say
14 it's not currently an exhibit?

15 MR. AHEARN: No, it's not, ma'am.

16 ACTING CHAIRMAN CARMODY: Yeah. I'd like to
17 have -- yeah. Let everybody see it. Maybe the parties
18 should have a copy and we'll have a copy.

19 MR. AHEARN: Very good, ma'am.

20 ACTING CHAIRMAN CARMODY: Thank you.

21 Member Black, you had one more question or
22 another --

23 MEMBER BLACK: Just from a standpoint of the
24 people who are trying to follow what's going on here
25 outside, I guess, John, maybe I don't want to question

1 staff, but for informational standpoint, was not this
2 airplane inspected again after 587, John?

3 MR. CLARK: Yes, it was.

4 MEMBER BLACK: And do you feel comfortable on
5 relating anything that was found?

6 MR. CLARK: You're talking about 903?

7 MEMBER BLACK: Yeah. Yeah. On 903.

8 MR. CLARK: We're going to cover that later.

9 MEMBER BLACK: We are? Okay.

10 MR. CLARK: Yes. That's -- that's the one
11 airplane that had the one finding around the lug, but
12 Brian's going to cover that later.

13 MEMBER BLACK: Okay. Thanks. I thought that
14 was it.

15 ACTING CHAIRMAN CARMODY: Is there anything
16 else from any of the parties?

17 CAPT. PITTS: Madam Chairman, one final
18 question from us, if you would, please.

19 ACTING CHAIRMAN CARMODY: Yes.

20 CAPT. PITTS: Dr. Lauber brought up a letter
21 that referred to a recommendation referencing deep
22 inspection. Was that per the maintenance manuals? I'm
23 not familiar with what that would exactly entail. Can
24 you tell us?

25 MR. CURBILLON: I'm not really familiar as

1 well because I'm Loads people, not Structure people.
2 But what I know, there was the standdown inspection but
3 also other complementary inspections. But not only the
4 standdown one but there was specific inspection
5 requested at that time.

6 CAPT. PITTS: And so, you think that there
7 were specific items outlined in -- in follow-on
8 communications?

9 MR. CURBILLON: I would say simply, to answer
10 your question, yes. What I would like to highlight is
11 due to the facts on loads, the inspections, the
12 standard inspection plan of GMM is one thing and there
13 were also additional requests coming from Airbus,
14 taking into account the severity of the event.

15 CAPT. PITTS: Thank you.

16 ACTING CHAIRMAN CARMODY: Any other questions
17 from the parties?

18 (No response)

19 ACTING CHAIRMAN CARMODY: Well, then thanks.

20 My thanks to the witnesses. You've been very, very
21 kind with your time and your information.

22 Why don't we take a 15-minute break and come
23 back and we'll resume? Mr. Ahearn, let's look at that
24 exhibit.

25 MR. AHEARN: Thank you.

1 (Whereupon, a recess was taken.)

2 ACTING CHAIRMAN CARMODY: First, I'll address
3 the request I had at the end of the last session from
4 American to include some additional e-mails or an
5 additional e-mail as an exhibit, and I'm going to not
6 allow that. The Exhibit 7LL from which Dr. Lauber was
7 reading was put in originally at the request of
8 American, and I think this is a subject between the two
9 parties which is a difficult one, and I'm aware of the
10 -- of the feelings running high and I think it's time
11 not to escalate by having one more exhibit on the
12 subject.

13 Let me just say from the Board's point of
14 view, we're not unaware of -- of the -- of the episode
15 of Flight 903. It's going to be part of our
16 investigation, and there's information we'll be
17 gathering on that, but this is not the forum for back
18 and forth about who knew what and which e-mails went
19 where. Most -- many of them are in the record, and I'm
20 going to leave it as it stands now.

21 So, Ms. Ward, I'd like to move forward with
22 the next witnesses. Would you identify them, please?

23 MS. WARD: Yes, I'd like to call Mr. Bernd
24 Rackers. Please raise your right hand.

25 Whereupon,

1 BERND RACKERS

2 having been first duly sworn, was called as a witness
3 herein and was examined and testified as follows:

4 MS. WARD: Please have a seat. Thank you.

5 Mr. Rackers, could you please state your full
6 name, your current employer, and your business address?

7 MR. RACKERS: My name is Bernd Rackers. My
8 employer is Airbus, and my business address is (German
9 address).

10 MS. WARD: And what is your current position,
11 and how long have you been in that position?

12 MR. RACKERS: My current position is I am
13 Senior Manager for Composite Technology in the field of
14 Materials and Processes, and I am in this position
15 since middle of last year.

16 MS. WARD: And could you please briefly
17 describe your duties and responsibilities and any
18 education and training that you may have received to
19 qualify you for your current position?

20 MR. RACKERS: Yes. My duties and
21 responsibilities are material selection, material
22 qualification, process development and introduction
23 into the serious production. So, I'm responsible for
24 manufacturing specifications and all the items which
25 are related to that. I got a Master's Degree in

1 Aeronautical Engineering in '84 at the Technical
2 University of Acken. I joined a carbon manufacturer
3 for four years, and in '88, I joined Airbus, and I
4 always was in the field of materials and processes and
5 developed in this field into my current position.

6 MS. WARD: Thank you.

7 Madam Chairman, I find this witness qualified
8 and now pass it over to Dr. Matthew Fox.

9 ACTING CHAIRMAN CARMODY: Yes, Dr. Fox,
10 please proceed.

11 DR. FOX: Thank you.

12 EXAMINATION

13 DR. FOX: Good morning, Mr. Rackers.

14 MR. RACKERS: Good morning.

15 DR. FOX: I would like to discuss composites
16 manufacturing at Airbus this morning, and I understand
17 that you have a presentation regarding this topic.

18 MR. RACKERS: Yes, Mr. Fox. Thank you.

19 I've prepared a brief presentation to
20 introduce you into the subject of composites, and I
21 would like to cover the various items of that, like a
22 brief introduction, what is the reason for composites
23 for us to introduce them, what is our experience with
24 them. I will focus on the materials qualification
25 approach, on the manufacturing principles. So, I've

1 prepared a small review to show how a fin box is
2 manufactured. I will focus on quality assurance
3 processes, and I will present some factual results we
4 gained in this investigation on behalf of NTSB.

5 Let me first introduce what this composite is
6 about. It's, as I said, it's composed of two major
7 elements. It's fiber, carbon fiber or fiberglass, but
8 I would like to focus on carbon fiber as we have used
9 this material on the fin box, and we have a second
10 constituent that's the matrix, as we call it. I refer
11 always in this presentation to carbon epoxy in this to
12 make it clear that we're using more advanced materials
13 than you may know from homework or do-it-yourself work.

14 These two forms, there is a second step where
15 the raw material is made in an industrial process where
16 the fiber and the matrix are joined in a process we
17 call pre-impregnation. So, we impregnate at a certain
18 supplier to the form of pre-preg, pre-impregnated.
19 It's an industry standard for aerospace engineering
20 manufacturing with these materials to get a material
21 which provides good mix of resin and fiber and which
22 allows us to use it under our standard.

23 So, we are making parts out of this pre-preg
24 which is in itself not a material because it's weak,
25 it's not cured. So, we do not have any properties we

1 can use. That's why we make the material in the
2 process and we have to be very careful with this
3 process.

4 The reason why we are using it, we have some
5 fundamental differences to metallic structures. We
6 have effectively no sensitivity to fatigue for aircraft
7 structures. We have superior properties which offer
8 significant gains which you can use for performance
9 increases of the aircraft, and we don't have any
10 corrosion for this kind of material. So, we have some
11 operating advantages.

12 The introduction of composites, and I would
13 stress this a little bit more in the next slide, it was
14 made after carefully evaluating the informal
15 performance and we started the secondary structure,
16 like fairings. We checked the worldwide environmental
17 conditions and I will explain later why we checked the
18 environmental conditions, because there were some
19 effects of it on the behavior of composites, and we did
20 extensive lead-fleet programs to follow the first part
21 which we introduced.

22 When we look back to 1972 when the actual
23 unit was introduced, we had some glass fiber or
24 fiberglass reinforced fairings. So, secondary
25 structure, like the leading edges of the vertical

1 stabilizer. We -- excuse me. We used also the first
2 spoilers made in carbon fiber reinforced composite. We
3 did an in-service flight on the A300 B2B4 and
4 effectively was A300-200. There was a first serious
5 applications of carbon epoxy parts, like spoilers, air
6 brakes and to rudder in the same configuration as we
7 have it today.

8 With the A310-300 in '85, as you have heard
9 before, we introduced the first carbon epoxy primary
10 structure on a civil transport aircraft, the vertical
11 tail plane, what is referred to here as fin. At the
12 same time, there were major NASA programs also on the
13 potential application of carbon epoxy for horizontal
14 tail planes and for vertical tail planes of civil
15 transport. So, we were at the same knowledge base as
16 the industry was worldwide.

17 Following that introduction of primary
18 structure in A310-300 and A300-600R, we introduced more
19 primary structure in the A320 family which was done in
20 '88, '87-88. So, we added the horizontal tail plane
21 and the flaps in carbon epoxy. The A340 saw some
22 further development. We got the first vent structure.

23 What does that mean? We have a tank made from carbon
24 epoxy. The HTP in this aircraft is a trim tank, so
25 it's fueled, and it was the first vent structure.

1 In our latest aircraft, we have the bulkhead
2 and the QV made of carbon epoxy that was introduced
3 this year into service. It's the A340-60 and for the
4 A380, we are planning and it's currently in the
5 manufacturing to add the center wing box in carbon
6 epoxy. So, we are on a step-wise approach to introduce
7 more and more composites in order to get these
8 operational advantages, and we used this step-wise
9 approach in order to get experience, in order to get
10 information and, of course, to be always on safe ground
11 with this introduction of new materials.

12 Up to now, with our fleet of A320 family,
13 A300, and A310 family and A330, A340 family, we get
14 more than 40 million flight hours with primary
15 structure in carbon epoxy.

16 I would now like to talk about material
17 qualification approach and how we performed when we
18 introduced that and we used the building block approach
19 or perimeter testing which you can see here and I will
20 focus my presentation on the generic part of this
21 perimeter testing which was the lower end, containing
22 the coupons, small test samples that we derived,
23 generic data for the material, and some element
24 testing. The rest of the building block approach was
25 covered by the structure, our stress colleagues, and we

1 will see the same parameter of testing of the building
2 block approach in the presentation of Mr. Winkler.

3 So, we used all these data which have been
4 generated in the process for the certification of the
5 aircraft. That doesn't mean we tested approximately
6 1,500 samples on this lower coupon level in order to
7 get a good database and in order to take into account
8 all the effects which may affect the performance of
9 this material, like moisture, temperature, which I will
10 explain in the next slides, and aggressive mid-year
11 effects in a way that we don't have any detrimental
12 effect by, for example, hydraulic fluid which is kind
13 of aggressive to all kind of materials.

14 We did a statistical evaluation of all this
15 data. The allowables, and I will find it out later on
16 again, were based on MIL Handbook 17, and I will give
17 more information later. What is essentially listed is
18 all our design loads taken for the worst case for
19 carbon epoxy and that's a wetted structure, where the
20 structure or the specimen gained moisture, and I will
21 explain in my next slides about this moisture gain of
22 composites.

23 There's one slide and this is used also as a
24 -- this test is also used in the investigation. So, I
25 will refer later on as well to this kind of testing

1 that's what we call DMA test. It's a dynamic
2 mechanical analysis. It shows, in easy words,
3 reduction of stiffness of a small specimen with the
4 temperature, and as you see here on this graph, excuse
5 me, we have in the area of the aircraft, only nearly no
6 effect of the temperature, and we will have a kind of
7 weakening, and I say weakening or softening because
8 it's an industry term. It does not weaken the
9 structure because we are way beyond our service
10 temperatures which is up to 80 centigrade or, in
11 American terms, 175 F for the fin box, and you see here
12 the effect of moisture. When moisture gets into the
13 composite, it reduces the thermal capability of this
14 material. So, there's a reduction of the softening
15 temperature to higher -- to lower temperatures, but all
16 of that happens well beyond the service envelope of the
17 material and of the -- sorry -- of the aircraft.

18 These figures here show -- this graph is for
19 the dry specimen, for the dry structure. This one, 1,
20 4 and 2 percent material, refers to a moisture
21 conditioning of a specimen which has been done at --
22 with a moisture of 70 percent relative humidity. So,
23 the level of moisture in the environment can --
24 responsible for the moisture gain and also for the head
25 of the gain, and we have 1.6 for 85 percent relative

1 humidity. So, you see there is an effect of moisture
2 of the environment on the moisture gain.

3 These figures are relevant for the specific
4 material we used, and you can see here in this slide
5 that it was this material, 913, which has been used on
6 the accident aircraft. So, these are original data.

7 I'm going to talk about moisture gain. We
8 have to be aware about the fact that the moisture gain
9 comes to equilibrium at the end, and we have also to
10 take into account that we can dry the specimen
11 completely, and in the term of the investigation, I
12 will show that the material regains its original
13 performance when it's dried again. So, we don't have
14 any, what we call, aging effects. So, it's fully
15 reversible. So, we can moisturize the specimen and we
16 can dry it again and then we have the same performance
17 and that is also part of the presentation I will give
18 to you today later on.

19 You may ask how we come to the conclusion
20 that 85 percent relative humidity has a correlation to
21 the service of the aircraft that was done by an
22 extensive Lead Fleet investigation. We did them on
23 spoilers flying worldwide, Indonesia and to other
24 countries where we have hot and wet environment, in
25 order to cover the most severe effects on the

1 structure, and we also based our assumptions on
2 simulation based on worldwide weather data, and we
3 checked for the extreme conditions and we came out that
4 85 percent relative humidity which we do for specimen
5 saturation, for specimen conditioning and for structure
6 conditioning, covers or is conservative in terms of the
7 worst case conditions we may have worldwide, and we
8 never found a structure which had more moisture in it.
9 So, that was driven by a conservative approach.

10 Let me now talk a little bit about the
11 allowables we determined for the coupon test results.
12 As I said, it was based on approximately 1,500
13 specimens, and we established B-values. Those are
14 minimum values which are required to do the loads
15 calculation and the stress calculations of the parts.
16 We applied method at that time, request by FAA. There
17 was no MIL Handbook 17 available at that time. It was
18 in discussion. So, what we used the method in
19 discussion with FAA and later on, these methods were
20 included in the MIL Handbook 17 draft. So, we borrowed
21 the industry standard and this Handbook 17, although
22 it's a handbook, it's relevant for our composite for
23 our generation.

24 The MIL Handbook 17 was established in '88-89
25 as its first version and including a computer program

1 which is called Stat 17, which we applied since then,
2 also for alternative material qualifications we
3 performed afterwards.

4 As I said before, this composite material,
5 and when we get it to our manufacturing shop, the -- it
6 is not a material. It's a raw material which has no
7 properties in itself, no mechanical strengths. So, we
8 make the material in this process. It does mean we
9 have to carefully evaluate all the processes when we
10 make the parts and we call it cure cycle because we
11 cure -- cure the material at elevated temperature of
12 250 F, for example, and we have to be sure that we do
13 it correctly and we have to ensure also that possible
14 forces deviations by the tolerance of the measuring
15 devices and equipment we use. That we analyze them and
16 define a process which covers this potential tolerances
17 in the manufacturing and we have to ensure that we
18 check the material for this processing tolerances we
19 have in manufacturing. So, it's time, it's
20 temperature, it's the heat up in the autoclave where we
21 cure the parts, it's the pressure, and, of course, we
22 check for the combination to establish a safe
23 processing window for the material.

24 Let me go now to the manufacturing. I would
25 like to present -- excuse me -- a small video because

1 it's very difficult to show on slides how this fin box
2 is manufactured, and I would like to show you how we do
3 it in our manufacturing side.

4 Video -- "The fin or vertical stabilizer is
5 in foil located at the rear of the fuselage which gives
6 the aircraft directional stability. The fin is
7 composed of different parts, including the leading and
8 trailing edges and the rudder. The main component is
9 the fin box which is built of composite material that
10 has been in use in the aircraft industry for the last
11 20 years.

12 Airbus has been manufacturing the fin box in
13 the same way and using the same type of material since
14 the structure was first certified in 1985. The type of
15 composite used to build the fin box in the A300-600 is
16 a carbon fiber reinforced plastic, known as carbon pre-
17 preg, made of 60 percent carbon fiber pre-impregnated
18 with 40 percent resin. Airbus purchases the raw
19 material from approved suppliers who conduct their own
20 quality checks and who are regularly audited by Airbus.

21 From the moment the material arrives at the
22 factory and is placed in cold storage, only specialized
23 technicians who have undergone a three-year
24 apprenticeship are authorized to handle it. On arrival
25 at the factory, each new batch of pre-preg is examined

1 by Airbus quality inspectors to ensure compliance with
2 the supplier's certificate. Samples are tested by
3 specialist technicians using approved procedures. For
4 every five hours of production time, one hour is
5 dedicated to quality testing.

6 Mechanical testing shows the strength
7 advantage of the material. Here, pre-test calculations
8 are being verified by loading a narrow strip with a
9 weight of more than 8,000 pounds. Carbon fiber as well
10 as being strong can be modeled and shaped to maximize
11 strength in particular areas.

12 The carbon fiber is cut using a computer-
13 controlled high-precision cutting tool. The tool also
14 labels each section for later use. Here, a technician
15 is preparing various layers to form a lug, a section
16 that connects the fin box to the fuselage. He
17 carefully positions each pre-assigned section,
18 documenting every new layer he adds. This super-
19 imposition of layers of carbon fiber creates a
20 contoured shape that uses the direction of the fibers
21 to give the part its required strength. Each lug has
22 its own individual logbook in which every action,
23 inspection and check is recorded as it occurs
24 throughout all stages of the manufacturing process.

25 The part is then pressurized and cured in an

1 autoclave to bind the layers together. To ensure there
2 are no flaws inside the lugs at this stage, each one is
3 scanned individually using ultrasonic equipment. The
4 part is dipped in water and images are relayed to a
5 monitor to check for defects. The different colors on
6 the monitor indicate the differences in thickness of
7 the part.

8 The fin box is the main component of the fin,
9 measuring about 26 feet high and 10 feet wide at its
10 broadest. It is this component that provides the core
11 inner strength of the fin which must withstand the
12 loads imposed on it during flight. To ensure the
13 strength and reliability of the fin box, a modular
14 production method is used to manufacture an integrated
15 structure. The documented lengths of carbon fiber are
16 manually laid over light alloy molds by technicians who
17 are regularly evaluated to ensure they maintain the
18 highest level of skill. These modules are then placed
19 in position according to a precise design pattern that
20 maximizes the strength of the component. They are
21 secured laterally and longitudinally by a system of
22 flanges and reinforcement layers. The resulting
23 structure forms one half of a fin box shell.

24 The pre-cured lugs can now be manually
25 integrated into the fin box shell. There are six lugs

1 on each aircraft, each composed of an inner and outer
2 part. The corresponding inner and outer parts of each
3 lug are subsequently bonded together with the skin to
4 form powerful attachments between the base of the fin
5 and the fuselage. Before integration, the lugs are
6 again thoroughly inspected and documented to ensure
7 they meet the required standards.

8 Once all the lugs have been integrated, the
9 skin of the fin box shell is carefully laid by hand
10 over the outer surface. A foil bag is placed over the
11 skin inside which a vacuum is produced to compact the
12 assembly and ensure it is entirely smooth. After the
13 foil has been removed and the skin checked, the module
14 assembly is turned through 180 degrees to allow for
15 final preparation before curing.

16 Additional strips of carbon fiber are laid
17 longitudinally between the modules to further reinforce
18 the strength of the fin box in this direction. The fin
19 box is then vacuum bagged again to apply pressure
20 throughout the curing process. To attain its ultimate
21 resilience, the completed half section of the fin box
22 is heated in an autoclave to a temperature of 250
23 degrees Fahrenheit and subjected to a pressure of
24 around 100 pounds per square inch for at least 10
25 hours. Curing is performed in a single cycle to ensure

1 uniform strength of the final structure.

2 Once the section leaves the autoclave, the
3 outer vacuum foil is removed and a demolding process is
4 performed. Special tools are used to retrieve the
5 light alloy molds from the carbon fiber frame. The
6 structure is then cleaned and machined to the required
7 shape. To verify the quality of the part after curing,
8 it is tested with ultrasonic equipment. This ensures
9 there are no air bubbles or separations between layers
10 or wrinkling of the outer layers. Areas with complex
11 geometry, such as around the lugs, are double checked
12 and scanned by hand to ensure the part meets quality
13 standards. The two half sections of the fin box and
14 the central framework that holds it in place are now
15 brought together for assembly. A special jig locks the
16 parts firmly in position while they are riveted
17 together. Holes are then drilled through the lugs and
18 a part known as a bushing is fitted through the hole.
19 Large bolts will be passed through these bushings
20 during final assembly of the aircraft to join the fin
21 to the fuselage. The rudder and all other component
22 parts of the fin are added at this stage before a
23 thorough systems check.

24 Here, a test is being performed to check the
25 rudder systems. A detailed manual inspection of the

1 fin is then performed. The rudder and fin are
2 disassembled after checks, carefully crated in custom-
3 built jigs and loaded aboard Airbus's transport
4 aircraft for delivery to the final assembly line where
5 they are checked again at the point of installation on
6 the aircraft."

7 Let me strengthen some points on the quality
8 assurance process. You have seen elements of that in
9 the video, but additionally, it's necessary that we
10 have at least three major steps in the quality
11 assurance process we apply on the manufacturing of the
12 parts.

13 The one which is before the production start
14 is that we certify and verify all the materials we
15 have, the processes, the tools, and also the materials
16 which are necessary to manufacture these parts and we
17 perform batch tests and incoming inspections of all of
18 these parts. That's the first step.

19 The second step is careful process control
20 and monitoring. Again, as I said, the material gets
21 its performance in the process, so we have to monitor
22 and to control all the processes we apply, and at the
23 end, we do a final inspection which is, as you have
24 seen, an NDI inspection, for example, but also we do
25 thickness measurements, visual inspection, whether we

1 find some anomalies or not.

2 The requirements we have in place in our
3 manufacturing side are specifications for materials,
4 for batch release testing. We have manufacturing
5 specifications in a general part and we have also a
6 part-specific manufacturing specification and we have
7 and I will show you an example later, a quality
8 requirement sheet where we fix the quality requirements
9 for the individual components of parts.

10 You see here this picture of the NDI process,
11 but again this NDI process is only one part of the
12 whole quality assurance process, and you see here this
13 so-called squirter technique where the ultrasonic sound
14 is accompanied by a waterjet to the structure. You
15 have seen it also in the film.

16 Then we go to the quality requirement sheets.

17 We specify the material for the workers. So, the
18 quality requirement sheet is a part of the drawing
19 which the worker has in hand when he makes the part.
20 We check for the material. We check for the process
21 specification, that he applies the correct ones and is
22 aware of what he has to do, and we have also specific
23 requirements in terms of quality, for example, for
24 porosity and that sheet is part of the drawing which
25 comes along when he manufactures the part.

1 I would like now to show some results of the
2 testing we performed on behalf of NTSB and the
3 investigation and on behalf of BEA, which is the French
4 equivalent of the NTSB. We did the tests in our
5 Materials and Processes Lab in Bremen, Germany. All
6 the tests were witnessed, were part of the NTSB
7 investigation, fully in line with the procedures we
8 have agreed on.

9 We have chosen the DMA testing which I have
10 explained earlier on in my presentation because we have
11 established in '85 this specific method to check the
12 thermal behavior of the material. We have all the
13 reference data available, and we can check by this DMA
14 whether the material performs to specification in terms
15 of its behavior, its thermal behavior, and whether the
16 curing process was done right with this component when
17 it was manufactured. So, again, as I said, it checks
18 the material performance and it checks whether it was
19 correctly manufactured in terms of the curing process.
20 All tests were performed in our lab and witnessed by
21 the BEA on behalf of NTSB.

22 The first thing we did when we got the
23 specimens which were extracted from part of the fin and
24 in this case extracted from the fin box in the upper
25 part, so we checked for the actual moisture content at

1 the time when we got the specimen. So, this moisture
2 content has no relation to the moisture content at the
3 time of the accident. It's just a check that we can
4 verify our data. We did in the past in '85 with
5 different moisture content. So, you see the drying
6 curve and we established a moisture content of .6
7 percent.

8 Then we compared that to the data we gained
9 in the qualification in '85 with exactly the same
10 material. You can see here that we have got results
11 from 144 Centigrade, I must admit there's no Fahrenheit
12 available for that, and you see the reduction with
13 increasing moisture content. The actual moisture
14 content -- sorry. This figure is for the moisture
15 content of 1.2 and this is the moisture content of 1.6
16 which is equivalent to the service condition we have
17 established. So, the maximum service moisture we can
18 get as a reference point.

19 We checked for the .6 percent moisture
20 content and we got it with 134 Centigrade which is 273
21 F which is above the estimation of the -- of the curve
22 and we did also redrying of the specimen. So, we got
23 the moisture out and we came exactly to the same
24 results we had in '85. So, we got a moisture -- a DMA
25 temperature of 149 or 300 F which is in the schedule of

1 the tests we performed in '85. So, we had to -- at
2 which a mean value of 144, standard deviation of 5, and
3 it was based on 33 specimens. So, we have proven that
4 first the material performed as it should perform. We
5 also can show that the moisture gain and the
6 performance shows a reversible behavior, that we can
7 regain the performance with this kind of material, and
8 we have proven that in this term of the accident
9 investigation.

10 Let me summarize my presentation. The
11 material was qualified according to the certification
12 standards. We did a statistical evaluation in
13 accordance with MIL Handbook 17. We used the industry
14 standard building block approach. We checked the
15 processing window for the manufacturing process. We
16 have a reliable manufacturing technique verified and
17 approved quality procedures for the manufacturing.

18 In terms of our contribution to the excellent
19 investigation and with the methods we applied, that we
20 can say in terms of DMA tests, that the material was
21 found to be within the specification and also with
22 reference to the curing process we applied at that
23 time, we can say that the fin box was manufactured to
24 the specification.

25 Thank you very much.

1 DR. FOX: Thank you. I guess, thank you for
2 that very comprehensive presentation.

3 In -- in that, you had mentioned you had done
4 numerous coupon tests, and you mentioned that you had
5 done -- studied environmental effects, among other
6 things. Were -- was also -- were there studies of
7 impact damage or the effects of impact damage or
8 delaminations or, you know, how was that addressed in
9 -- in the -- at the coupon level?

10 MR. RACKERS: Yes, it was addressed at the
11 coupon level. There is tests called compression after
12 impact. So, we subject the specimen of 4X6 inches to
13 impact energy level of approximately 30 to 50 Joules,
14 but this is done to check the behavior of the material
15 in order to classify the material between different
16 kinds of materials in order to select an impact-
17 resistant material.

18 DR. FOX: Did you also do open hole tests in
19 tension?

20 MR. RACKERS: Open hole tests and also filled
21 hole test in compression were part of the element tests
22 and that was mainly done in the Structures -- in the
23 Stress Department at that period of time.

24 DR. FOX: Okay.

25 MR. RACKERS: Specific to the part and

1 specific to the lab.

2 DR. FOX: Moving on to some of the NDI
3 inspections during manufacturing, what types of defects
4 would you expect to be able to detect using the non-
5 destructive examination?

6 MR. RACKERS: By the ultrasonic NDI, we can
7 detect porosity and we can detect separation, whether
8 they occurred by non-proper application of pressure in
9 the process or by the finished parts. So, we can
10 detect separation and we can detect what's porosity.

11 DR. FOX: When -- in terms of the porosity,
12 what's the -- the -- or -- or -- or separations, what's
13 the maximum size, defect size, that's permitted?

14 MR. RACKERS: The maximum defect size depends
15 on the location of the structures. So, we have -- the
16 smallest one is 75 square millimeters and the biggest
17 one is 250 square millimeters. It depends very much on
18 the location. So, we have tougher requirements for the
19 lower parts where we have the highest loads.

20 DR. FOX: Okay. Does -- does the size depend
21 at all upon the geometry of the defect or -- or
22 position within the thickness?

23 MR. RACKERS: No.

24 DR. FOX: What -- what types of anomalies or
25 defects would be present that could affect strength or

1 stiffness of the material that may not be detected by
2 non-destructive inspection?

3 MR. RACKERS: We guarantee that we affect --
4 that we detect all the defects which reduces the
5 strength by this process and by loads calculations.
6 So, we verify also what kind of defect has to be
7 detected and we can detect with the equipment which you
8 have seen 36 millimeters squared.

9 DR. FOX: So, essentially, through your
10 materials qualification and coupon testing and -- and
11 that whole process defines what type of defects you
12 need to detect and then you use the -- the correct
13 method to find those types of defects?

14 MR. RACKERS: Yes.

15 DR. FOX: As far as, you know, looking at
16 fiber volume fraction and the overall richness of -- of
17 resin within the composite, how -- how does -- do an
18 overall resin-rich or resin-poor material have -- what
19 effects does that have on the strength of the material,
20 the stiffness?

21 MR. RACKERS: Well, there is an effect, of
22 course, and there's a severe effect if the fiber volume
23 content is too high. So, we have to keep, as we say,
24 the resin in the component, in the process, and we have
25 established a limit. First, when we started, we have

1 established a limit of 64 percent fiber volume
2 fraction. What we found in some areas, a higher fiber
3 volume fraction, and we justified that also this higher
4 fiber volume fraction is okay, but as soon as it is
5 higher than 70 percent, then we have a limitation from
6 structures point of view and we can identify the fiber
7 volume content by thickness measurement. That's also
8 non-destructive testing.

9 DR. FOX: So, -- so, what -- what range do
10 you target for fiber volume fraction? You mentioned 70
11 percent being the upper --

12 MR. RACKERS: Yes, but 66 is quite okay.

13 DR. FOX: And at the lower end?

14 MR. RACKERS: At the lower end, -- sorry. I
15 forgot to answer this part of the question. On the
16 lower end, we have more resin in the component, but
17 there's no effect on the structural strength of the
18 component.

19 DR. FOX: Okay.

20 MR. RACKERS: So, we manufacture, as you have
21 seen with a lot of aluminum blocks, and it's not very
22 easy to seal them carefully, so that we prevent the
23 resin from going out. So, we manufacture with excess
24 resin, and the excess resin may build up in certain
25 areas of the part and we check that there is no effect

1 on the structural strength of it.

2 DR. FOX: Okay. I guess one -- one more item
3 within non-destructive testing and defects. Would you
4 be able to detect stacked delamination using NDI, the
5 ultrasound?

6 MR. RACKERS: Could you please explain what
7 -- what you mean by stacked delamination?

8 DR. FOX: Well, often referred to as multiple
9 delaminations within one area through the thickness.

10 MR. RACKERS: Through the thickness in
11 several plies.

12 DR. FOX: Yes.

13 MR. RACKERS: We can locate, if we have an
14 indication, we can exactly locate which ply the
15 indication is. So, we can detect that.

16 DR. FOX: Okay.

17 MR. RACKERS: The standard procedure is to
18 (1) the stress material, see if there's an indication,
19 then we check manually again whether there's a defect
20 and what the exact size and location is in order to
21 verify whether the defect is critical or not.

22 DR. FOX: So, then there is -- that gives you
23 an overall size and location of the defect but doesn't
24 -- I guess it doesn't really tell you how many, you
25 know, how many layers are affected?

1 MR. RACKERS: By manual inspection, we can
2 also detect the location of the defect, and we can also
3 --

4 DR. FOX: Sure.

5 MR. RACKERS: -- detect whether we have
6 several delaminations.

7 DR. FOX: Okay. So, you check it from both
8 sides, then, at this stage?

9 MR. RACKERS: Yes.

10 DR. FOX: I guess you have a number of checks
11 during -- during manufacturing to, you know, ensure
12 that you have a good cure cycle, temperature cycle on
13 your cure. How -- how did -- what -- what -- what
14 methods do you use to verify the cure during
15 manufacturing?

16 MR. RACKERS: Well, we monitor the cure
17 cycle. We have established temperature thermal couples
18 in order to monitor the temperature, and we know
19 exactly which temperature of the various ones is
20 critical. So, we have a philosophy of following the
21 slowest thermal couple we have, as we say, because we
22 have to guarantee that each individual part of the
23 resin gets at least the temperature and time which it
24 needs to cure correctly and that's why we established
25 the slowest cure thermal couple philosophy, and the

1 thermal couple location is selected in such a way that
2 we are able to determine that. So, for example, we go
3 for thick areas where we have the slow response of the
4 material to the temperature increase and we check for
5 the thick areas and that determines normally the
6 slowest thermal couple.

7 DR. FOX: Okay. And did -- in the
8 development of the -- the manufacturing process, did
9 you include travelers or -- or any kind of other
10 material along with the parts being manufactured?

11 MR. RACKERS: Yes, that's also part of the
12 quality assurance process. So, we have travelers to
13 check whether the processing conditions in the
14 autoclave are okay. So, we check for the temperature
15 and time exposure of the traveler specimen.

16 DR. FOX: And would there have been a
17 traveler specimen at the time the accident fin was
18 manufactured?

19 MR. RACKERS: Yes, there was a traveler
20 specimen, and this traveler specimen after the process
21 was tested by the short-term shear test, which was
22 referred to as ILS test.

23 DR. FOX: Okay. I guess another item
24 involving the cure, what's the role of curing agents in
25 the process?

1 MR. RACKERS: Well, epoxy resins consist of
2 basic epoxy resins and curing agents to build up the
3 linkage in the epoxy resins and there are curing agents
4 or hardeners, and there's also in this specific
5 material a curing agent which speeds up the curing
6 process.

7 DR. FOX: And when is that added to the
8 material or included in the material?

9 MR. RACKERS: It is added when the resin is
10 mixed prior to the pre-impregnation process and that is
11 done at the manufacturer which -- who supplies us the
12 material.

13 DR. FOX: And then, is there a check when
14 that material comes in as to the content --

15 MR. RACKERS: Yes.

16 DR. FOX: -- of the --

17 MR. RACKERS: We establish later on in the
18 process the chemical analysis of the resin system which
19 you do in-house. At that time, we had checks at the
20 manufacturer that we corrected there and the correct
21 amount is in there.

22 DR. FOX: Okay. Let's see. I guess moving
23 towards porosity and -- and within the material, what
24 -- what are the void concentration limits permitted?

25 MR. RACKERS: Well, at that time, period of

1 time, there was no direct correlation to the void
2 content, but we checked on the reduction of the signal
3 strength of the NDI signal of the ultrasonic and it was
4 a reduction of minus 6 decibels which was in thick
5 areas to conservative.

6 DR. FOX: Okay. I guess in the -- that's how
7 you detect it within -- with the NDI during
8 manufacturing. What -- what are -- what are your
9 target limits for porosity or void content?

10 MR. RACKERS: In terms of content?

11 DR. FOX: Yes, and volume content.

12 MR. RACKERS: Well, as I said, at that time,
13 there was no definite definition for that, but later
14 on, we established that we have at least 2.5 percent
15 maximum level.

16 DR. FOX: Okay. Then in the -- in the layout
17 as -- during the manufacturing process, you -- you --
18 you take great care to ensure that -- that layers are
19 placed, and I guess in the final process, you -- you
20 check the thickness to ensure that the -- the -- that
21 -- is that the only check to ensure that you have the
22 correct layup and the correct number of layers?

23 MR. RACKERS: Well, that's the final check.

24 DR. FOX: The final check.

25 MR. RACKERS: When it's too late, normally if

1 something is missing. So, we have a laydown book.
2 When each individual layer is laid down, it's checked
3 that it's in place and it's correctly in place and you
4 may have seen that on the film, that the guy made some
5 remarks that it is put in place.

6 DR. FOX: And then, if -- if there is the --
7 a problem in the final check with the thickness
8 measurement, then what -- what is done at that point?

9 MR. RACKERS: Well, at first, you make a
10 calculation whether the fiber volume content is okay.
11 So, as I said, it's critical to have at least correct
12 fiber volume content and not to have -- go to a higher
13 fiber volume. If there is an indication, then we check
14 locally at this area, and if we come to the conclusion
15 that there is something wrong, we make a core drill in
16 order to analyze the exact number of plies and also the
17 exact fiber volume content that can be done by a
18 microsection analysis of the picture.

19 DR. FOX: Okay. And then, with -- during the
20 -- in the standard process, there are cores drilled out
21 in the lugs themselves. What type of tests do you do
22 on -- on those cores?

23 MR. RACKERS: I'm not aware of this test at
24 the moment. So, it's possible to take it. If there is
25 any question on that, so we can check, for example, for

1 DSC, if we have a concern on the curing. We can check
2 also for the exact number of layers and so on.

3 DR. FOX: Okay.

4 MR. RACKERS: But I'm not aware of a routine
5 check for this.

6 DR. FOX: It's not done on a routine basis?

7 MR. RACKERS: No.

8 DR. FOX: I guess in -- when doing the lugs,
9 you -- you use pre-cured halves. Could you talk a
10 little bit about why that is done?

11 MR. RACKERS: Well, the reason is quite
12 simple. We have approximately 200 plies in this area in
13 the -- in the bigger -- bigger lugs and as soon as we
14 have to manufacture big parts, we have to be careful.
15 That's one point.

16 The second point is that the geometry is very
17 complex in this area, so that we have to ensure a good
18 quality and that led to the decision to separate the
19 lugs into an inner and an outer one and to manufacture
20 them before, so that we established a good quality in
21 the lugs themselves, and you have seen the precautions
22 which we've taken so these lugs are cured in master
23 frames in order to achieve the exact geometry and to
24 achieve a good quality. So, quality is the answer.

25 DR. FOX: And then, what -- what sort of

1 surface preparation techniques are done as those are --
2 are co-bonded in -- in the final assembly?

3 MR. RACKERS: Well, as I said, we do a co-
4 bonding process. That means one part is already cured
5 and we mate it to a non-cured part, and we do two steps
6 of surface preparation for this bonding, and the first
7 step is that we apply a pater ply before curing and we
8 remove the pater ply after curing and, additionally, we
9 do sanding.

10 DR. FOX: And then, what sort of cleaning or
11 other operations do you do to ensure that you avoid
12 contamination?

13 MR. RACKERS: We do some -- just some water
14 cleaning. That's sufficient. And we take care, of
15 course, that we have only freshly-cleaned and fresh
16 parts where the pater ply has been removed shortly
17 prior to the following operations. So, if these parts
18 have to be stored, then the rule is that the pater plys
19 has to be on to protect it.

20 DR. FOX: Okay. So, I guess moving to -- on
21 to the accident vertical stabilizer, and I think you
22 pretty well covered the work that you had done on our
23 behalf, and I guess to summarize, did you -- you did
24 not find any evidence of in-service damage or
25 degradation in those tests?

1 MR. RACKERS: No, not from our tests. For
2 the rest of the tests we are responsible.

3 DR. FOX: Okay. And then, I guess the final
4 -- final topic was regarding fractographic
5 examinations. In -- in support of the structures,
6 structural testing, did -- did your -- your group do
7 any fractographic support in those tests?

8 MR. RACKERS: Fractographic. Depends on the
9 wording, but we did analysis of the internal -- the
10 inner quality, as we say, of the part which was tested
11 in the full-scale test in order to establish a picture
12 how the inner quality is, whether we have deviations
13 and whether these deviations have any consequence. So,
14 there is a full report available on it, and I think I
15 provided that to -- to the Structures Group and we did
16 the investigation.

17 DR. FOX: Okay. But as far as examining
18 fracture surfaces or anything of that nature, no?

19 MR. RACKERS: No, not -- we did not do it.

20 DR. FOX: Okay. That's all the questions I
21 have. Thank you.

22 ACTING CHAIRMAN CARMODY: Thank you, Dr. Fox.
23 Are there other questions from the Technical
24 Panel? Yes, Dr. Kushner.

25 DR. KUSHNER: Yes. Hi.

1 MR. RACKERS: Good morning.

2 DR. KUSHNER: Just like to follow up. In
3 response to Dr. Fox's question about how you
4 characterized defects that are found ultrasonically,
5 you said basically that you just do it by the area.

6 MR. RACKERS: Yes.

7 DR. KUSHNER: The delamination. So, does
8 that mean that basically a circular delamination would
9 be considered equivalent to an elliptical delamination
10 with a 10:1 aspect ratio, if they have the same area?

11 MR. RACKERS: Yes.

12 DR. KUSHNER: Okay. And also then in terms
13 of where they sit through the thickness, the same
14 delamination between a zero degree tape and a plus or
15 minus 45 fabric, it would be considered the same
16 severity, as the same size defect, between a zero
17 degree tape and a plus or minus 90 -- 090 fabric?

18 MR. RACKERS: Yes.

19 DR. KUSHNER: Okay.

20 MR. RACKERS: Can I make a remark on that?

21 DR. KUSHNER: Sure.

22 MR. RACKERS: Okay. These limits were
23 established covering the full strength capability of
24 the structure, and this represents the lower limits
25 and, of course, we introduced, when we did the full

1 scale test, for example, much bigger delaminations in
2 various sequences of the testing. So, again we have a
3 conservative approach on that. So, that's the reason
4 why we do not care what location the size. So, the
5 structure is able to carry the full strength with even
6 much higher delaminations. That is part of the
7 witnessing of Mr. Winkler.

8 DR. KUSHNER: Okay. Thank you.

9 One other thing now. When you do the
10 thickness check, what is the resolution? You know, how
11 closely spaced are the points that you do that at?

12 MR. RACKERS: Well, the thickness test is
13 done with conventional thickness measuring --
14 measurement tools, and we do have, of course, some
15 limitations as soon as we get to very thin parts of the
16 structure, but if you have concern, then we do an
17 analysis which is -- goes more into the detail and we
18 do these core drills.

19 DR. KUSHNER: I'm sorry. I guess I didn't
20 express it clearly. I meant, points that you sample
21 the thickness at on the surface of the part, how often
22 do you do that?

23 MR. RACKERS: Oh, we have a test plan for the
24 sampling, and I don't know by heart exactly what it is.
25 I believe more than 100 points on the structure.

1 DR. KUSHNER: Okay. And in the lug area --
2 in the lug area, --

3 MR. RACKERS: Pick a number here.

4 DR. KUSHNER: Okay. Is that concentrated
5 heavily towards the lug area and the transitions
6 between the lug and the skin?

7 MR. RACKERS: I think we have some more
8 measuring points in the lug areas, and it's more
9 randomly distributed than the rest of the fin box.

10 DR. KUSHNER: Thank you. Okay. That's it.
11 Thank you very much.

12 ACTING CHAIRMAN CARMODY: All right. Thank
13 you, Dr. Kushner.

14 Moving then to the parties, I'll begin with
15 the FAA, Mr. Donner?

16 MR. DONNER: Once again, we have no
17 questions. Thank you.

18 ACTING CHAIRMAN CARMODY: American, Mr.
19 Ahearn?

20 MR. AHEARN: Thank you, Madam Chairman.

21 Just a few. Mr. Rackers, little did I know
22 that we would meet again when we said good-bye in the
23 elevator this morning.

24 MR. RACKERS: Yes, that's correct.

25 MR. AHEARN: Good to see you again.

1 MR. RACKERS: Yes.

2 MR. AHEARN: Just a few topics I'd like to
3 discuss with you.

4 From your film, I believe it indicated that
5 there have been no changes to the fin box since its
6 initial certification in 1995, is that correct? I'm
7 sorry. 1985.

8 MR. RACKERS: That's correct, as far as
9 A300-60 is concerned, and we are still using this type
10 of fin box, this type of manufacturing technique for
11 SC40, for example, but with some adjustments to the
12 loads. But the concept is the same.

13 MR. AHEARN: Okay. And from a certification
14 standpoint, that -- there's no recertification?

15 MR. RACKERS: Not as far as I'm aware of.

16 MR. AHEARN: Okay. Also, I believe I heard
17 that the fin when it was designed was designed to be
18 interchangeable with the B2B4.

19 MR. RACKERS: I am not aware of
20 interchangeability between B2B4 but definitely between
21 A300-600R and A310.

22 MR. AHEARN: Okay. So that, it was designed
23 --

24 MR. RACKERS: But the lugs are designed in
25 the same way. So, we have the same layout of the lugs,

1 so of the connections on the fuselage.

2 MR. AHEARN: So, --

3 MR. RACKERS: So, I'm not aware whether we
4 can change from 300-600R composite fin to a B2B4 metal
5 fin.

6 MR. AHEARN: So, from an evolution standpoint
7 then, the lug size was designed to fit into the pre-
8 existing empennage starting from the B2B4 to the 310 to
9 the 300-600R?

10 MR. RACKERS: As far as the geometry is
11 concerned, I believe so, yes.

12 MR. AHEARN: Okay. Could you have designed a
13 stronger composite lug without the limitation of trying
14 to fit into a pre-existing empennage?

15 MR. RACKERS: Of course, we could have
16 designed the stronger fin box with no problem, but we
17 have exceeded 1.93 limit loads. So.

18 MR. AHEARN: Okay. Specifically talking
19 about the lug from a design standpoint, can you discuss
20 not from a specific load standpoint but from -- from a
21 composite standpoint as to how you overlay the
22 composite material? Can you describe how the loads --
23 really what I'm looking at is -- is the design of how
24 you do your overlays. Are there ways to increase the
25 strength by overlaying the composite material,

1 particularly as it relates to the lugs, at different
2 angles, at different -- or use a different process when
3 it's connected to the -- obviously the metal clevis?

4 MR. RACKERS: What do you mean by overlaying?

5 MR. AHEARN: Well, when you -- the material
6 is overlaid at different angles as it's being built.

7 MR. RACKERS: Yes.

8 MR. AHEARN: Okay. In designing that, what
9 kind of testing have you done to look at different
10 overlays to increase the strength of the lug?

11 MR. RACKERS: Well, it's more a question to
12 the Stress because Stress is responsible for the design
13 and to get the correct layout sequence and the correct
14 layout, but as you have seen on the video, there was
15 highly-contoured part and carefully-adjusted layers
16 with different angles, and as far as I know, it is
17 optimized in terms of strength.

18 MR. AHEARN: Okay. So, you wouldn't have
19 anything to do with the strength --

20 MR. RACKERS: No.

21 MR. AHEARN: -- of the lug?

22 MR. RACKERS: No.

23 MR. AHEARN: Maybe Mr. Winkler can help us in
24 that regard.

25 MR. RACKERS: Yes.

1 MR. AHEARN: Okay. Thank you, sir.

2 Just a couple more topics. On the composite
3 lug, do you have any sense that -- maybe this is Mr.
4 Winkler's question as well, but I'll -- I'll ask it.
5 Do you know what the effect of the size of the hull is
6 relative to the edge distance on -- on the strength of
7 the lug?

8 MR. RACKERS: That is his question as well.

9 MR. AHEARN: Okay. Then two follow-on
10 questions to your video. It appears, and it may have
11 been because of the angle that I was seeing it, but
12 when -- in the video, when you showed the development
13 of the lug, the lug actually appeared to be quite
14 smaller than actually the 300. It may have been a 320
15 lug in there but it also may have been the angle that
16 I've been looking at it.

17 Could you tell me how does the design and
18 geometry of the other aircraft in the Airbus family
19 differ from the -- the 600, and -- and specifically
20 what I'm talking about is in the -- in the lug area?

21 MR. RACKERS: Well, of course, the 320 is a
22 smaller aircraft with smaller lugs. So, what you have
23 -- what you have seen on the video is actually an A300-
24 600 lug. So, for A340 we have a thickness increase due
25 to the loads of this aircraft. So, we have a different

1 load for each aircraft and, of course, we adjust the
2 lug thickness to the load.

3 MR. AHEARN: And -- and to your knowledge,
4 there's no certification difference?

5 MR. RACKERS: What do you mean by
6 certification difference?

7 MR. AHEARN: Certification of the
8 construction of the fin.

9 MR. RACKERS: Not as far as I know.

10 MR. AHEARN: Okay. Do you know if the -- the
11 -- the damper or the hull side that the bushing and
12 then the clevis pin goes through, do you know if they
13 are different on any of your other fleets?

14 MR. RACKERS: I'm not exactly aware of that.

15 MR. AHEARN: Okay. Maybe that's a question
16 for Mr. Winkler as well.

17 MR. RACKERS: Yes.

18 MR. AHEARN: Madam Chairman, that ends my
19 questioning. Thank you very much.

20 ACTING CHAIRMAN CARMODY: Thank you.

21 Allied Pilots, Captain Pitts?

22 CAPT. PITTS: Thank you, ma'am.

23 Good morning.

24 MR. RACKERS: Good morning.

25 CAPT. PITTS: On the A300-600 vertical

1 stabilizer, is it -- is it correct that the -- that the
2 attachment to the fuselage is by means of the all-
3 composite lug that is essentially just an extension of
4 the -- of the composite side skin?

5 MR. RACKERS: Yes.

6 CAPT. PITTS: And when a hole is cut through
7 that composite to form the lug, the fibers that run in
8 each ply, I think, are interrupted. I think you showed
9 that in your video, and therefore the loads normally
10 carried by those fibers are redistributed. Are they
11 then through the resin and the adjoining fabric pieces?

12 Can you go back into that a little bit, how that --
13 how that -- that works for us because of the -- of the
14 hole that's been placed in there?

15 MR. RACKERS: Well, that's standard procedure
16 to carry loads from a skin size, skin type of design,
17 into a point, and it was fully certified this way. Of
18 course, you may argue that the fibers are cut, but that
19 is not of any concern.

20 CAPT. PITTS: Okay. Do any other
21 manufacturers using composites in the vertical
22 stabilizer build attach points to the stabilizer
23 fuselage relationship in this same fashion?

24 MR. RACKERS: I'm not aware of that, no.

25 CAPT. PITTS: You mentioned that if the

1 structure reached 1.93 of the limit load, the limit
2 load again is the highest loads expected to be seen in
3 service?

4 MR. RACKERS: Yes, that is per definition
5 I've seen before in this investigation and in the
6 course of this hearing.

7 CAPT. PITTS: We saw higher loads in those in
8 this flight?

9 MR. RACKERS: Pardon?

10 CAPT. PITTS: And we saw higher loads than
11 that limit load in this flight?

12 MR. RACKERS: In which flight?

13 CAPT. PITTS: In the Flight 587.

14 MR. RACKERS: We saw at least loads in the
15 same order of magnitude as the original statement of
16 one of the other witnesses.

17 CAPT. PITTS: And we've seen limit -- and
18 we've seen that limit load exceeded in other flights as
19 well?

20 MR. RACKERS: As far as the statement of the
21 other witnesses are concerned, yes.

22 CAPT. PITTS: In your opinion, would you want
23 to go back and revisit that load value used for the
24 design of this composite structure?

25 MR. RACKERS: As I said, per the other

1 witnesses, we fully complied with the certification
2 requirements, and we established a limit load, and I
3 think that is sufficient.

4 CAPT. PITTS: Okay. What other Airbus
5 commercial airliners use the same attached design and
6 composite materials for attaching either the vertical
7 stabilizer elevators as used in the A300-600 aircraft?

8 MR. RACKERS: As far as the attachment design
9 is concerned, all of our current flying aircraft have
10 exactly that same design, having six attachments by
11 fins. For the smaller attachments, but for other
12 loads.

13 CAPT. PITTS: Okay. Thank you.

14 I noticed the reference to the quality
15 control, and I just wanted to clear up something. Do
16 Airbus employees in the Composite Section perform their
17 own quality assurance functions or is an independent
18 quality assurance department used there?

19 MR. RACKERS: Our Manufacturing side are
20 qualified to Standards 9000, and we do the quality
21 testing by all, of course.

22 CAPT. PITTS: Okay. Can you speak to the
23 repair on the aircraft in question, 053?

24 MR. RACKERS: No. Because Stress has to
25 analyze in terms of deviations from the manufacturing.

1 They have to analyze the consequence of that and have
2 to fix that.

3 CAPT. PITTS: Do you -- well, then do you
4 know if there was ever -- was this ever the -- was this
5 the first-ever kind of repair on a lug?

6 MR. RACKERS: No.

7 CAPT. PITTS: As a -- as a composite expert,
8 have you seen this kind of repair in -- in other
9 applications?

10 MR. RACKERS: Yes, I've seen some other and
11 they were certified and tested by the Stress.

12 CAPT. PITTS: Do you know at what point in
13 the testing or in the manufacturing process that --
14 that defect occurred in that lug?

15 MR. RACKERS: No.

16 CAPT. PITTS: Do you know what might cause a
17 discontinuity in the -- in the -- in the structure?

18 MR. RACKERS: Sorry. I didn't get the word.

19 CAPT. PITTS: Discontinuity. Do you know
20 what might have caused the discontinuity that caused
21 the concern in that lug?

22 MR. RACKERS: No, I'm not aware especially of
23 that.

24 CAPT. PITTS: All right, sir. I have no
25 further questions.

1 ACTING CHAIRMAN CARMODY: All right.

2 And Airbus, Dr. Lauber?

3 DR. LAUBER: Just a couple of quick questions
4 for clarification.

5 Mr. Rackers, you -- you used the term
6 "traveler specimen" in some of your testimony. It
7 might be helpful for some people if you'd explain what
8 a traveler specimen is.

9 MR. RACKERS: A traveler is composite
10 material which is put into the autoclave parallel to
11 the structure but the traveler does not form the same
12 -- from exactly the same batch of material, and it's
13 just used to verify whether the curing process is okay.

14 DR. LAUBER: Okay. Thank you.

15 MR. RACKERS: It is not a cut-out of the
16 structure.

17 DR. LAUBER: Thank you.

18 You also testified with regard to testing
19 done on the cores that are from the drilling process.
20 Aren't there torsional strength tests done on those
21 cores?

22 MR. RACKERS: Yes, it's possible.

23 DR. LAUBER: Okay. One other question.
24 After the grinding process of -- of the pre-trimmed
25 lugs is completed, what kind of quality test is

1 performed on the part at that point?

2 MR. RACKERS: Well, there's an additional
3 quality test to check for surface resistance because
4 one reason for the grinding is that part of our
5 lightening strike -- lightening strike protection
6 concept is that we have connectivity between the skin
7 plys and the lug plys in order to transfer electricity.
8 So, we do internal connectivity that we at least have
9 access to the fibers which conduct electricity.

10 DR. LAUBER: Okay. Thank you.

11 No further questions, Madam Chairman.

12 ACTING CHAIRMAN CARMODY: Thank you.

13 I know a number of the board members have
14 been to Hamburg to see that process of the
15 manufacturing. It's quite impressive.

16 Member Hammerschmidt, any questions from you?

17 MEMBER HAMMERSCHMIDT: No questions. I'm one
18 of those that have had the opportunity to witness the
19 manufacturing process firsthand and I certainly
20 appreciated that -- that accommodation.

21 I would just like to say that was a very nice
22 presentation this morning, --

23 MR. RACKERS: Thank you.

24 MEMBER HAMMERSCHMIDT: -- and I would like,
25 if you could, to have a copy of -- a hard copy of the

1 slides of the Bremen testing part of your presentation
2 at some point.

3 MR. RACKERS: Which one?

4 MEMBER HAMMERSCHMIDT: The -- the -- the
5 testing at Bremen.

6 MR. RACKERS: Okay. Yes, it's in the
7 exhibit.

8 MEMBER HAMMERSCHMIDT: Yes, but just an
9 additional copy.

10 MR. RACKERS: Yes, of course.

11 MEMBER HAMMERSCHMIDT: Just that one part of
12 your presentation. Thank you. That's all I have.

13 ACTING CHAIRMAN CARMODY: Member Goglia?

14 MEMBER GOGLIA: No questions.

15 ACTING CHAIRMAN CARMODY: Well, anything
16 further from the Technical Panel?

17 (No response)

18 ACTING CHAIRMAN CARMODY: Anything further
19 from any of the parties?

20 (No response)

21 ACTING CHAIRMAN CARMODY: Why don't we come
22 back at 1 and start with the next witness? Thank you.

23 (Whereupon, at 11:53 a.m., the meeting was
24 recessed for lunch, to reconvene this same day,
25 Thursday, October 31st, 2002, at 1:00 p.m.)

1 and responsibilities and any education and training
2 that you may have received to qualify you for your
3 current position?

4 DR. ILCEWICZ: In this position, I support
5 Airworthiness Assessments, Certification for Composite
6 Structures. Based on the experience associated with
7 that in areas, such as Materials and Processes, Design,
8 Analysis, Manufacturing, Maintenance, Substantiation as
9 related to Certification, I develop education, both
10 within the FAA and for industry, and I also take those
11 experiences to apply and help direct what research is
12 done by the FAA in Composites.

13 MS. WARD: And what's your educational
14 background?

15 DR. ILCEWICZ: In 1980, I started off at the
16 Boeing Company. I had a Master's Degree and a
17 Bachelor's of Science at that point in time, worked
18 under their Advanced Composite Developmental Program
19 for roughly two years. At that point in time, I was
20 able to get an educational leave of absence. I had
21 funding from the National Science Foundation and Boeing
22 also gave me a contract where I went to get my Ph.D. at
23 Oregon State University. I returned to the Boeing
24 Company in 1984, worked on a number of programs, got
25 experience supporting 737, 757, 767 service problems as

1 related to composite materials in the early days.

2 Towards the end of the '80s, I got involved
3 in developing design methods allowables that would
4 consider environmental effects damage tolerance,
5 helped establish design requirements and objectives in
6 the composite world. This was all prior to the 777
7 going to a composite empennage.

8 Through the '90s, I was involved in a large
9 NASA program to help develop composite fuselage
10 structure for transport aircraft. I was the principal
11 investigator for that, and the last assignment I had at
12 Boeing before coming to the FAA was with 757-300
13 program on wing structures.

14 MS. WARD: Thank you, Dr. Ilcewicz.

15 Madam Chairman, I find this witness qualified
16 and now pass it over to Mr. Brian Murphy for
17 questioning.

18 EXAMINATION

19 MR. MURPHY: Good afternoon, Dr. Ilcewicz.

20 I'd like to discuss the following topics with
21 you today: certification of composite structure, the
22 requirements for static and damage tolerance, static
23 strength and damage tolerance, and then, finally, NDI
24 and visual examination of composite structure.

25 Before I begin addressing the main topics,

1 would you tell us what's been required of you during
2 this investigation?

3 DR. ILCEWICZ: I was on NTSB Structures Team
4 which has been very thorough in this area of
5 composites. We've looked at many different possible
6 failure scenarios for the vertical fin, developed a
7 fault tree to help guide our efforts in all different
8 areas. So, I would say that just about all of my
9 experiences were brought to bear, including my
10 knowledge of certification, manufacturing and
11 maintenance over the years, as well as going back to
12 being able to apply basic stress analysis principles,
13 laboratory techniques and effectively reverse engineer
14 the failures that we have observed in the accident to
15 the extent that we would be able to support the other
16 working groups and confirm that the loads were as
17 predicted.

18 MR. MURPHY: Okay. Let's move on into
19 certification of composite structure then.

20 Based on your review of the materials and
21 your work with the Structures Group to date, have all
22 the areas -- all the key areas been addressed in the
23 certification of the Airbus -600R vertical tail?

24 DR. ILCEWICZ: They have. They followed a
25 traditional building block approach that started late

1 '70s/early '80s, pretty extensive effort. They used
2 all of the available guidance materials, and they also
3 used whatever engineering standards existed in the
4 composite world at that point in time.

5 MR. MURPHY: In general, are there any --
6 possibly maybe from a historical perspective, in
7 general, are there any differences in the approaches
8 used to certify the -600R composite structure versus
9 your knowledge of other transport category composite
10 structure?

11 DR. ILCEWICZ: Well, my exposure up until
12 coming to the FAA was primarily with the Boeing
13 Company, and in the late '70s/early '80s, there was
14 many military programs. I was always in Commercial
15 Division, but many of the people from my group ended up
16 going to the military, and the NASA organization had
17 also contracted Boeing, Lockheed and McDonnell-Douglas
18 to look into the feasibility of using composite
19 structures on commercial aircraft.

20 We started very much parallel to the types of
21 efforts that Bernd talked about from the Airbus side
22 with the development of secondary structures to see how
23 the materials would react in the environment, and then
24 as we gained confidence and insight, we started to move
25 the primary structures, and the first primary

1 structures, there was in the early '80s, these NASA
2 prototype tail structures. The one I was most familiar
3 with was the five ship sets of horizontal stabilizers
4 on 737 aircraft that flew an entire life on those
5 aircraft, but that particular exercise didn't lead to
6 production implementation of -- of composite empennage.
7 That did not occur until the 777 did that in the early
8 '90s.

9 But from a historical perspective, the
10 collective insights gained from military exposures as
11 well as these early NASA prototype programs led to
12 Advisory Material 2107-A which was developed in the
13 mid-'80s, and at that point in time, the European
14 authorities came together with the U.S. authorities,
15 including experts from all major industry groups and
16 even military support, to help define the guidance that
17 exists in 2107-A.

18 MR. MURPHY: Thank you.

19 Could you give a basic description of some of
20 the key areas that are addressed during the
21 certification of composite aircraft structure?

22 DR. ILCEWICZ: Well, Bernd started off with
23 an area that is very important. It forms the basis of
24 the development and certification that you have
25 established proper material in manufacturing

1 fabrication controls because much unlike what goes on
2 in the metal side, you are effectively advancing the
3 material to a final state in your factory, and you have
4 to understand what happens as that occurs at all scales
5 that you're using to help substantiate the structure,
6 and as you go up the building block ladder of the
7 manufacturing and design, I like to say that they're
8 integrating their efforts. They're understanding how
9 the specific details that ends up on drawings can be
10 manufactured and reproduced, and in the end, you want
11 to make sure that whatever you develop in a database to
12 support certification is something that you can count
13 on; i.e., the manufacturing will carry on with the
14 quality assurance procedures, such that you will always
15 reproduce that same type design. So, that becomes the
16 initial very critical area.

17 You develop data, statistically significant
18 data that represents the lowest levels of the building
19 block that oftentimes start with basic material
20 properties but also include things such as joints and
21 elements that can be tested in large quantities and you
22 get confidence that you understand the variation of the
23 material and then, as you move up the building block,
24 what you're doing oftentimes is substantiating that
25 what you had developed as a basis is correct and you

1 learn from each level of testing what the load paths
2 are versus what you expect to have from your structures
3 analysis, and all of that comes together and culminates
4 in a full-scale evaluation which we refer to sometimes
5 as static strengths substantiation.

6 At a full scale, you're also concerned with
7 evaluating fatigue as it is done in the metals world,
8 and you are also concerned with evaluating damage
9 tolerance which will balance your static strength
10 requirements. Finally, you're concerned throughout
11 this process with what happens once that structure is
12 put in service. So, you're establishing databases and
13 guidance for what should be done in maintenance and
14 repair, and all of that collectively is the main key
15 areas of relevance to our discussion today.

16 MR. MURPHY: Is it possible that you could
17 maybe just summarize which -- some of the safety issues
18 and structural details that would drive the design of a
19 composite structure?

20 DR. ILCEWICZ: Yes. Some of them began to be
21 discussed earlier before the lunch break. In
22 composites, it's recognized that details, such as
23 access holes or bolted joints or lug holes, other
24 details, such as stringer runouts, attachments to ribs
25 and so on, that those become some of the critical

1 structural detail that will drive static strength.

2 Also as related to composite materials, there
3 has been, as directed from the early experiences with
4 2107-A, a need to consider non-detectable damage that
5 could come with in-service from accidental events, such
6 as a foreign object impact, and so that becomes another
7 critical part of static strength substantiation.
8 Environmental effects are also important to that. To
9 balance that off, you consider the issues associated
10 with damage tolerance where you're moving to much more
11 serious damage and you're using maintenance to help you
12 in that regard together with your database and
13 understanding of the structure to be able to tolerate
14 that more severe damage and also realizing that it's
15 damage that maintenance can find reliably.

16 MR. MURPHY: All right. Let's move on into
17 static strength and damage tolerance then.

18 Mr. Goldberg, could you put up the Exhibit
19 7W, please, Page 2? Once that's up there, Dr.
20 Ilcewicz, referring to that exhibit, could you explain
21 to us then, you know, the difference between ultimate
22 limit load levels as they would be related to composite
23 structure design considerations and, say, the loads
24 that would normally occur in each flight?

25 DR. ILCEWICZ: I don't have a very good view

1 of -- of this graph. I believe it's the exhibit that
2 I've submitted. It's -- it's not in -- in color. So,
3 I'm going to have to help highlight some things that
4 are there that you can't see.

5 Okay. There should be a line that is
6 invisible because of the color that was used right in
7 this neighborhood or somewhere in that -- it's not
8 drawn very well to scale. Did it show me doing that
9 when I was doing this?

10 MR. MURPHY: I'm going to try and give him a
11 color one to put under the visualizer, Dr. Ilcewicz.
12 I've got one. They're trying to -- he's manipulating
13 the one we currently have.

14 DR. ILCEWICZ: Okay. Now, the yellow line
15 shows the limit load. Now, within the regulations,
16 there are regulations that will define what is needed
17 for ultimate load, and those considerations are --
18 would be driven in design by the design details that I
19 described with access holes and bolted joints and so
20 on.

21 Also, for ultimate load per what's
22 recommended within the Advisory Circular and it's been
23 practiced within the composite world, is you also have
24 to be good for damage that can't be found by the
25 maintenance program, and in addition to that, you have

1 to have a lifetime worth of operating loads. It's
2 essentially a coupling of fatigue substantiation with
3 ultimate load and the worst case environment. So,
4 those become some of the things that are considered in
5 sizing for static strength.

6 Limit load is not taking advantage of the
7 fact that damages that could degrade the strength below
8 ultimate but are detectable using current maintenance
9 practices or scheduled maintenance practices are things
10 that would have a limit load requirement. In addition
11 to that, there are a number of other things that will
12 fall under considerations for fail safety and some of
13 the rogue manufacturing defects that are often
14 considered for composites, such as weak bonds, and we
15 define the structure to still be able to have those
16 massive or gross defects and still be able to carry
17 limit load, knowing that they can be detected.

18 If you look at the curve and try to go below
19 limit load and consider operating load levels that the
20 aircraft sees, it's going to be different for every
21 structure. If it's a fuselage, the operating loads
22 every cycle are fairly close to limit load. In the
23 case of air foil structures, they can be significantly
24 below limit load.

25 So, this is a diagram that I think was shown

1 before by the FAA without the composite substantiation
2 information on it.

3 MR. MURPHY: You may have answered this when
4 you were describing that ultimate load there, the
5 description, but what composite design details and
6 damage considerations are important for the static
7 strength and ultimate load requirements?

8 DR. ILCEWICZ: Well, it again would depend on
9 each structure. If it's a structure that's dominated
10 by compression loads, then oftentimes impact damage can
11 be a primary source. In the neighborhood of joints,
12 you oftentimes will have the considerations for the
13 bolt that joints as a driver.

14 When you dial in the fact that you want to be
15 able to apply a mechanical fastened repair throughout
16 the structure, you effectively move the joints away
17 from where they're normally located to all kinds of
18 other locations wherever repair's allowed of that
19 character, and so those tend to drive you in -- in
20 design of considerations for static strength.

21 MR. MURPHY: How are the effects of repeated
22 loads evaluated for composite aircraft structures?

23 DR. ILCEWICZ: Well, this is unique for
24 composite structures because it's understood at the
25 design screen levels that they work at, that most

1 manufacturers try to demonstrate a no-growth approach
2 to fatigue, and so oftentimes static strength and
3 fatigue substantiation will be coupled, and in doing
4 that, you're effectively demonstrating that in a number
5 of ways, that there is no growth occurring at the
6 repeated loads that are characteristic of that
7 particular structure being studied.

8 MR. MURPHY: Okay. Since we've -- since
9 we've mentioned it, what -- what load levels would
10 typically be required or needed for fatigue damage
11 propagation to become a problem with composite
12 structure?

13 DR. ILCEWICZ: It would vary with the
14 specific detail or damage being considered. It'd be on
15 the average of from 60 to 80 percent of the critical
16 strength that is being -- the critical detail that's
17 being applied to the -- the cyclic loads. So, if it
18 was a bolted joint, for example, it may fall somewhere
19 in the middle of that. If it was a more serious
20 damage, the SM curves or the fatigue cyclic curves tend
21 to get even flatter and they might approach more of an
22 80-percent number from the data that I've seen in that
23 area.

24 MR. MURPHY: What was done during the
25 certification of the -600R to substantiate the static

1 strength and fatigue resistance of the structure?

2 DR. ILCEWICZ: As I mentioned, they -- they
3 tended to follow what a lot of the other composite
4 programs since then have retained as standard, but this
5 was also done within the scope of the early NASA
6 programs, and that is, that prior to demonstrating
7 static strength capability to ultimate load, a lifetime
8 worth of loads with a statistical significance applied
9 to it, i.e., in the composite world, that means that
10 you increase the repeated loads by some value, apply
11 those fatigue loads for enough cycles, such that you
12 can represent what a lifetime is equivalent to, and
13 then you apply static load requirements for ultimate
14 load to that.

15 Now, they went through that as the first
16 substantiation of static strength and fatigue
17 insensitivity.

18 MR. MURPHY: All right. What design details
19 and damage considerations are important for now when we
20 get to the damage tolerance and requirements and damage
21 tolerance and limit load requirements?

22 DR. ILCEWICZ: Well, now you're moving into
23 rarer damages, damages that don't occur so often to the
24 structure, but you're also, because of what you've done
25 in design, you're usually moving to damage levels that

1 are detected visually with an inspection that would be
2 applied in maintenance.

3 Now, not all designs will follow that path.
4 Other manufacturers, other designs may push to
5 different means of inspection, but let's say that
6 you've used a visual cut-off for what you will use for
7 maintenance in your inspection procedures, and anything
8 that falls on the other side of that, i.e., is non-
9 detectable at that visible threshold, then that would
10 be subjected to the static strength requirement.
11 Damages that are detectable by visual means are -- are
12 going to be more severe damage and those would be
13 subjected to damage tolerance requirements.

14 Now, beyond that, oftentimes, depending on
15 what structure you're looking at and how it's
16 constructed, whether bonding's used in the structure,
17 there will be a certain amount of fail safety that will
18 also be developed which is a traditional damage
19 tolerance concept that you can lose a significant
20 portion of the structure and still maintain limit loads
21 with that structure missing.

22 In addition, in damage tolerance, there's a
23 Part E that relates to discreet source damages, such as
24 very large bird strikes in the case of a tail, as well
25 as the possibility of rotor blades and other things,

1 depending on what systems are in the proximity, and
2 oftentimes the loads that would be applied for that
3 requirement would be lower than limit load because when
4 that event occurs, it's known to the crew and they have
5 specific instructions they follow.

6 MR. MURPHY: Okay. Following the same line
7 that I did with the ultimate strength then, could you
8 tell me what was done during the certification of the
9 600R to substantiate the damage tolerance requirements?

10 DR. ILCEWICZ: Well, as well as I understand
11 it, they -- they realized as they went how tolerant
12 their structure was to damage. So, after they had
13 taken one of the articles through a lifetime's worth of
14 fatigue and demonstrated ultimate load, they put more
15 serious damages that would be detected in -- in
16 maintenance inspection, everything short of what I
17 referred to as fail-safe damages, and they carried
18 those damages for another lifetime equivalent with the
19 load enhancement factors for fatigue and then went back
20 and demonstrated ultimate load a second time and that
21 was with damage that would normally fall under 571
22 considerations.

23 The more serious damages that take us all the
24 way to lost sections of structure and taking out
25 elements, that was a limit load requirement was applied

1 to substantiate fail safety on those articles.

2 MR. MURPHY: Why is impact damage so
3 important in composite structure design?

4 DR. ILCEWICZ: Well, unlike metals, impact
5 can -- can have an important effect on compression and
6 shear or other "matrix-dominated" properties in
7 composite structure, and so if you were to impact a
8 composite, what'll happen is in the source of the
9 impact, over what area that impact covers. Oftentimes
10 you'll cause some localized fiber failure that are very
11 local to the impact -- impactor itself.

12 Standing out from that zone can be a myriad
13 of matrix cracks and delaminations that can become much
14 larger than the impactor itself, and these matrix
15 cracks and delaminations are -- are fairly complicated
16 in terms of how they interconnect and form through the
17 thickness of the laminate. I think the terminology
18 "stack delaminations" was described this morning. In
19 trying to understand the physics of impact damage, the
20 terminology "sublaminates" is often used, that a given
21 repeated stacking sequence of laminate will have a
22 characteristic damage state associated with impact
23 events, that oftentimes the matrix cracks and
24 delaminations will form in a characteristic pattern
25 which, if you understand for your specific design

1 detail, you can define these sublaminates through the
2 thickness.

3 Now, getting back to the issue of compression
4 and composites, they are sensitive to holes and
5 discontinuities in compression. If you load the
6 composite with the impact damage present, then the
7 individual sublaminates can buckle at some load level,
8 and they won't carry any more than the load that caused
9 them to buckle. They may have some post-buckling
10 response and pick up a little more load, but a
11 conservative assumption would be that when they start
12 to buckle, that the only load that goes through the
13 impact damage is the load that caused it to buckle, and
14 now the rest of the load that would ordinarily come
15 through that load path has to go around it and you form
16 a stress concentration and the stress concentrations
17 are both in plane and out of plane. The out-of-plane
18 stress concentrations could tend to grow the
19 delaminations, if the matrix was brittle enough. The
20 in-plane stress concentration tends to act as a
21 partially-filled hole and can cause compressive failure
22 at the edge of the impact, and so these all have to be
23 accounted for when you design and substantiate
24 composite structure.

25 I gave you a relatively simple description of

1 impact relative to what happens in -- in real structure
2 that has stiffening elements bonded and so on.

3 MR. MURPHY: This is really a two-part
4 question, the next one, but I've seen it depicted in
5 graphs several times, I believe it was once at the
6 Airbus conference, by both yourself and -- and Airbus.

7 How does the impact damage affect the
8 residual strength of the -- of the structure, and in
9 particular, how's it accounted for in the certification
10 analysis and testing of the structure?

11 DR. ILCEWICZ: Well, the -- the harder you
12 impact it, the more strength reduction you will get. I
13 think the curves that you're referring to indicate that
14 initially, as you start to increase damage size, which
15 can occur by increasing impact energy, you start to
16 drop down a relatively steep curve.

17 Now, as you impact it further and this is
18 characteristic of not just impact but other geometry of
19 -- of discontinuities in composites, whether it's holes
20 or rotor blade penetrations, such I studied in the
21 fuselage program at Boeing, you eventually hit
22 asymptote in that curve, and the -- the description of
23 that -- I don't have a graphic with me. I could draw a
24 graphic, if --

25 MR. MURPHY: That'd be fine.

1 DR. ILCEWICZ: -- you desire. The curve I'm
2 going to draw -- the curve I'm going to draw is often
3 referred to, whether it's in metals or composites, as a
4 residual strength curve, and what it -- what it's
5 illustrating is it's illustrating how damages of
6 increasing size affect the strength of the structure
7 and -- and that strength we refer to as a residual
8 strength.

9 Now, the -- the absolute geometry of -- of
10 these curves can vary, depending on the specific layup
11 and materials and so on. In the compression world,
12 they tend to be relatively steep at the start and they
13 flatten out. The tension world has far more dependence
14 on laminate layups, but the tension curves tend to be
15 significantly above the compression curves. So, they
16 only become drivers in -- in structures such as
17 fuselage, sort of pressurized.

18 Okay. So, if you look at that curve, as I
19 mentioned, close to the far left side, damage size is
20 approaching zero. You have a relatively high strength,
21 and then as you start to apply damage to the structure
22 of increasing extent and size, the curve starts to
23 bring down the strength and then eventually hits close
24 to asymptotic behavior, and so you reach a certain
25 damage size where you can't get much worse.

1 MR. MURPHY: I think -- I think you just
2 covered it with the other one. That one says the same
3 thing, I think. But --

4 DR. ILCEWICZ: Take me a bit longer to draw
5 it.

6 MR. MURPHY: Mr. Rackers covered some of this
7 material during his presentation, but what would be
8 some of the typical material variabilities and
9 processing defects that would be encountered in the use
10 of composites during their manufacture?

11 DR. ILCEWICZ: Well, because of the geometry
12 of the structure and bringing complicated geometries
13 together, you can expect that you'll see local
14 wrinkling, porosity, variations in the fiber resin
15 distribution, delaminations, things of that nature.
16 Occasionally, there's small inclusions of things of
17 that character.

18 MR. MURPHY: How would these -- these types
19 of problems be controlled -- I'm sorry. Let me
20 rephrase this.

21 How would these be dealt with in the
22 manufacturing of composite structure and such?

23 DR. ILCEWICZ: Well, what would be normally
24 done is at the time of certification, a certain
25 database is developed, oftentimes in the industry we

1 refer to it as effects of defects, but that usually
2 isn't the end of that activity because oftentimes
3 through the course of manufacturing, additional things
4 are -- over, you know, a long production run, a lot
5 more is going to be understood and found out, so that
6 database continues to increase over time, and those
7 defects by and large oftentimes because they're left --
8 if -- if it's written up in factory documentation in
9 the hands of the factory personnel, a conservative
10 assumption will be applied, such that they are allowed
11 only if they're at sizes that are given as acceptable
12 from a structures group.

13 You can get some more serious defects which
14 each time that occurs, a structures analyst would have
15 to get involved with the production engineers to decide
16 with where it's located and what type of defect it is,
17 whether or not it's acceptable or a repair has to be
18 applied.

19 MR. MURPHY: Back -- back to that issue then,
20 if we were going to be at the material level where Mr.
21 Rackers was discussing, the coupons and the samples
22 where you'd want to address these things, where you can
23 have issues with clamping it in the fixture, cutting
24 the coupon in the saw, what's used at that level to try
25 and account for that variability in those coupons that

1 are going to be used as the foundation for your
2 building block?

3 DR. ILCEWICZ: Well, the -- the specific
4 level that you're describing becomes one more of
5 material control, that we want to ensure that the
6 material that's being received and applied to the
7 product is invariant over time and is what we expect it
8 to be. So, there's a need for a material specification
9 and requirements within that specification that help
10 control and ensure that the material received is
11 applicable and can be applied to the product.

12 More important data is developed at levels
13 above that that consider the details that are going to
14 drive the static strength and damage tolerance design
15 sides of things, and a bolted joints database, for
16 example, would be needed for attachments and -- and
17 joints within the structure to cover that.

18 The relative magnitude of the two effects,
19 there can be manufacturing defects that are as serious
20 as bolted joints and -- and other design details within
21 the structure, but oftentimes they are not as lowering
22 in the strength of the structure as other things that
23 -- that have to be considered anyways.

24 MR. MURPHY: Are the design strain levels for
25 the -600R composite structure characteristic of that

1 used in other transport category aircraft?

2 DR. ILCEWICZ: Well, I'm not intimately
3 familiar with all areas of that aircraft, but from what
4 I've seen in the certification documentation, the
5 design strain levels that they are working their
6 structure to is conservatively on the low end of what
7 future Airbus and other aircraft that I'm aware of went
8 to.

9 MR. MURPHY: I was going to ask you to
10 summarize the static strength and damage tolerance for
11 continued airworthiness, but I think you covered that
12 in your opening questions -- questioning.

13 Let's -- how about -- are metal structures
14 subjected to the same type of testing that you
15 previously described from a static and fatigue test
16 point of view?

17 DR. ILCEWICZ: In metals world, because
18 they're not attempting to -- to demonstrate no growth
19 and they would have to go to very low design strain
20 levels to hope of being able to demonstrate that, it is
21 not traditional for a metal structure to go through a
22 fatigue substantiation and then follow that with a
23 static strength demonstration.

24 The reason why that has become a standard in
25 the composites world is because as we've gone through

1 fatigue substantiation, we would monitor the damage
2 that's present and we would realize that that damage is
3 not growing and so that was one measure of no growth,
4 but an additional measure of no growth is proving that
5 that structure can still handle the static strength
6 requirements and so that's why that is often done.

7 Now, that aspect of things and static
8 strength is crucial. It's something that we all drive
9 for with the 1.5 factor of safety as required by the
10 regulations, but it is not complete in terms of
11 structural substantiation. That's why we push for
12 damage tolerance demonstrations as well, and we rely
13 and work closely with what we demonstrate there with an
14 understanding of what's possible in service and also a
15 link with the maintenance organizations, so that they
16 make sure that they find any damage that would degrade
17 the strength below ultimate before that degradation
18 could lead to below limit.

19 Now, traditionally in the metals world,
20 damage tolerance evaluations involve crack growth,
21 multiple site considerations, and I did quite a bit of
22 that at the Boeing Company. Each company has different
23 ways of dealing with it. The -- the ability to predict
24 and the databases that support metals damage tolerance
25 gives us the confidence that we can establish a

1 relationship with defects that grow in -- in service
2 loads with the maintenance organizations and make sure
3 that that damage is found before a limit load is
4 compromised and -- and so, composites are also
5 subjected to the more serious damages for damage
6 tolerance substantiation, and in most cases, composites
7 also elect to apply a no-growth approach there, such
8 that the same residual strength, even though below
9 ultimate, can be retained even after cyclic loads
10 through the course of an inspection interval.

11 MR. MURPHY: Okay. Let's move on into the
12 area of non-destructive inspection. Where is NDI used
13 for composite structures in the aviation industry?

14 DR. ILCEWICZ: Non-destructive inspections,
15 such as ultrasonic techniques and -- and other methods
16 that are appropriate for composite materials, are used
17 in production. I think Bernd gave an example of how
18 it's used in production with A300-600 aircraft.

19 It's also used in scheduled maintenance. If
20 there is an aircraft structure that relies on NDI to
21 detect the damage and work with the maintenance
22 department, such that that type of technique is
23 selected in the inspection scheme, then it could be
24 applied for scheduled maintenance in that way.

25 It's also applied in scheduled maintenance

1 for those that use visual inspection schemes, such that
2 once the damage is first detected visually, the full
3 extent of the damage is mapped out and understood using
4 NDI, and then finally, NDI is also used in service for
5 unscheduled maintenance, and there's several examples I
6 can think of of unscheduled maintenance where some
7 anomalous event that occurs to the aircraft outside of
8 its design envelope. We've had incidences where an
9 aircraft is too close to the end of a runway and
10 there's some loose runway concrete, you know, sometimes
11 very sizeable concrete that the engines rev up and send
12 it into the tail section, and now even though there's
13 visual indications of the damage, because of the nature
14 of that loading and -- and that specific type of
15 scenario not being considered as a design criteria or
16 consideration for the structure, then you have to go
17 beyond the visual indications of damage and look at
18 what that type of loading might have done to cause
19 damage in other parts of the structure that may not be
20 visible, and so moving away from what's considered
21 realistic threats in terms of what's applied for
22 design, it's classified as what I referred to as an
23 anomalous event that would be covered by unscheduled
24 maintenance. Another example would be an overload
25 outside the design envelope.

1 MR. MURPHY: Do you think that this factory
2 NDI is capable of detecting all serious manufacturing
3 defects?

4 DR. ILCEWICZ: Factory NDI on its own is not
5 a foolproof scheme of catching all serious
6 manufacturing defects and this is recognized within the
7 composite industry. We rely on NDI as a means to
8 confirm that things were cured properly or bonded
9 properly but that cannot be the only technique applied.
10 You have to have other rigorous quality controls. The
11 best example I can think of relates to bonded
12 structure. Because if some contamination had gotten
13 into the bond line, years of experience has proven to
14 us that NDI is not a reliable indication of whether or
15 not there's a weak bond as we would refer to it, and so
16 you have to have other quality controls in place that
17 ensure, based on measurements within the factory and
18 control of all the materials that come in contact with
19 the structure as it's being fabricated, that the
20 contamination did not get into the structure.

21 Now, as an added fail safety, an approach
22 used for all bonded structure, and I'm distinguishing
23 bonded from cured structure in that you have an element
24 of the composite that has previously been cured out and
25 now it's being brought into an assembly possibly to

1 cure it with another piece of composite structure or
2 bonded to another piece of composite structure that is
3 either in a green state or an already-cured state, and
4 now those bonded surfaces, you have to rely on there
5 being no contamination at the location that that bond
6 is formed.

7 If there is contamination, then you can get
8 loss of bond strength over time. Now, what we've done
9 in the composite industry for bonded joints is we have
10 made them fail-safe, that we've desired and we've
11 designed in oftentimes referred to as "chicken
12 fasteners" or other design detail that would ensure
13 that even if somehow contamination got into that bonded
14 joint, the structure would still be able to carry limit
15 loads and you would have been able to catch the problem
16 through maintenance.

17 MR. MURPHY: Okay. What factors lead to the
18 selection of a particular inspection scheme for
19 maintenance of composite structures?

20 DR. ILCEWICZ: Well, it -- the particular
21 inspection scheme selected by the manufacturer is often
22 done in cooperation with the airlines. There's
23 oftentimes a manufacturer -- excuse me -- a maintenance
24 review board, and even before then, throughout the
25 course of development, the manufacturer works with

1 airlines and the inspection scheme is defined based on
2 their experiences with structures that are similar or
3 if they don't have a previous composite structure of
4 that type, it's understood that the types of damages
5 that come to the metal structure in the form of dents
6 and so on could prove to be significant in a composite
7 structure, and so there's a cooperation put forth, such
8 that when the design is developed, the design is
9 developed recognizing the desired inspection scheme,
10 and if someone were to want to use a visual inspection
11 scheme, which is characteristic of a lot of the damage
12 threats and what's done within the industry, then you
13 have to pay a penalty in terms of what design strain
14 levels you can work to.

15 If you were to want to apply an NDI
16 inspection scheme, you could get more aggressive in how
17 much weight you could save, but there would be more of
18 a maintenance burden on the airlines or maintenance
19 depots to maintain NDI inspection of the structure.

20 MR. MURPHY: So, I'm going to try and
21 summarize that for you, but if I say it wrong, please
22 correct me.

23 For the same given structure, then what
24 you're saying -- the same given structure, -- I'm going
25 to stay away from that.

1 How does the selection of the inspection
2 scheme for metals, metal structure differ from
3 composite structure?

4 DR. ILCEWICZ: Fundamentally, they're
5 essentially the same. There are decisions to be made
6 in terms of what inspection scheme you're going to
7 apply. You also have to have knowledge of what
8 different types of defects will do in degrading the
9 strength, and with those two pieces of information, you
10 can make a judgment to make the structure more robust
11 and enable inspection schemes that can range from
12 visual into more complicated NDI, if you desire to try
13 to move to higher stressor strain levels, and so that
14 aspect is -- is very similar, but the types of damages
15 you're concerned about in the metals world versus the
16 composites world are uniquely different, not only in
17 terms of threat but also in terms of the
18 characteristics of the damage. In the composites
19 world, as we described before, impact damage, there is
20 no metals equivalent of that in terms of something that
21 could degrade a compressive strength or a shear
22 strength.

23 In the metal side, you're primarily concerned
24 with a fatigue crack growth phenomena, and you define
25 your inspection procedures knowing the growth

1 characteristics of cracks, and in the composites world,
2 you understand the thresholds of detectability and the
3 damage stress from service, and you define your
4 inspection procedures accordingly.

5 MR. MURPHY: It would be fair to say then if
6 you -- if you choose to -- to push the -- push the
7 envelope with your design and achieve the maximum out
8 of the given material system for this composite
9 structure, you know, the maximum capability from it,
10 you'd be forced into an NDI, whereas if you stay away
11 and work in a much lower level, you could use the
12 visual inspections. I think that's what I've heard you
13 say through the course of this questioning.

14 DR. ILCEWICZ: Well, I think it's -- it's not
15 as simple as that in that NDI, as I had mentioned, is
16 still used in scheduled and unscheduled maintenance,
17 regardless of what's first used to detect damage, but
18 in principle, it's -- it's very close to the way you've
19 described it.

20 The one thing that I would like to add is --
21 I don't know if it's better to go back and try to
22 illustrate it on that curve. I don't think Airbus has
23 something -- while I'm drawing, I can talk. What I'm
24 going to draw in this curve is I'm going to draw what
25 -- what damage may be considered for a design that is

1 using visual means to detect things, such as impact
2 damage, and what would be the threshold of
3 detectability for that, and I'm going to label that
4 line something that would be forced to be applied as
5 the appropriate strength parameter for an ultimate load
6 level in the structure, and then I'm going to try to
7 show the -- the 1.5 difference from that and associated
8 for limit, and then I'm going to try to demonstrate or
9 show a range of -- of damage sizes that are -- are
10 possible as accidental damage events in real service.

11 Now, for -- for static strength requirement,
12 you're looking at a need to consider and understand
13 what damages bring you to this ultimate load level and
14 make sure that all of that is covered in your static
15 strength substantiation. Now, I've put here the full
16 gamut of threats and this is an increasing damage size.
17 So, obviously these are more likely to occur and these
18 may become extremely rare.

19 Oftentimes this could be improperly-designed
20 composite structure on -- on the order of a massive
21 hole, you know, maybe 10 to 15 inches in -- in diameter
22 or greater, but you're starting to approach the
23 asymptote of the curve and even though those events are
24 extremely rare, we have found that to occur in service
25 and so you're making sure that damage that, you know,

1 obviously can be found probably even in a walk-around
2 without problems is still able to meet the requirement
3 of limit load which is the highest load expected in
4 service.

5 Now, if you were to become aggressive in this
6 and try to apply an NDI approach, then, you know, sure,
7 you could raise the level at which you would apply your
8 ultimate load requirement for that. We'll call that
9 ultimate with an advanced NDI scheme, but at the same
10 time you've shifted that, you've also shifted that,
11 you've also shifted your limit, and now your limit, you
12 know, is conceivably going here, and under those
13 circumstances, you don't have the same ability to
14 maintain the highest load expected in service if you've
15 now applied an NDI scheme and you've tried to increase
16 the design strains you're going to work the structure
17 to.

18 So, you -- you've to take this whole thing
19 collectively in trying to make decisions as to which
20 inspection scheme is the proper one to apply, and you
21 have to realize and work with the airlines and
22 operators on, you know, what has been found in service
23 and through my course of time at the Boeing Company,
24 anything that would degrade strength of this level and
25 composites is, you know, a once-in-10-year-type event,

1 but nevertheless, you still have to be concerned that
2 those are possible and be damage tolerant in case they
3 ever occur.

4 MR. MURPHY: I want to ask you about the --
5 the first AD that came out after 587. The FAA asked
6 for a visual inspection and then immediately -- not
7 immediately but then soon after that changed from --
8 from a visual inspection immediately following the
9 accident to NDI in this past Spring.

10 Can you summarize why that -- why that change
11 happened from one type to the other?

12 DR. ILCEWICZ: The -- the course of events
13 immediately following the accident, it was not a whole
14 lot of facts and data as we've shared throughout the
15 course of this investigation available obviously at
16 that time, and the first activity performed by the FAA
17 was close communication with Airbus and whatever quick
18 and dirty sizing or numbers we could run ourselves to
19 try to understand what level of damage would be
20 necessary before you would reach loads that are as high
21 as expected in service and to the level where
22 potentially a catastrophic event, such as the accident,
23 would occur.

24 It was determined at that time because Airbus
25 shared with us that they had designed their structure

1 to be fail-safe in the lug attachments, i.e., they
2 could completely eliminate one of the lug attachments
3 and still carry limit load and there was other data
4 available to them as well as our rough calculations,
5 that we realized that a visual inspection was
6 appropriate because it could be done very quickly.
7 That was one piece of information that led to the
8 visual inspections.

9 The other piece of information was the
10 realization that a repair was performed on that
11 aircraft and not knowing the full history of that
12 repair, whether it was done in the factory or done in
13 the field, we wanted to make sure that a repair of that
14 magnitude was not characteristic of all airplanes in
15 service and in the event that that was a possible
16 contributor, and so the original advisory or
17 airworthiness directive went out to -- to quickly
18 inspect the fleet.

19 MR. MURPHY: We've talked about 90 -- Flight
20 903 throughout the hearing. Now, based on the Exhibit
21 7Q, that was the only aircraft after the inspections
22 that -- that led up to the second AD had any findings
23 and then that fin was not returned to service.

24 Could you tell me why that fin was not
25 returned to service from the FAA's point of view?

1 DR. ILCEWICZ: Well, through the course of
2 these meetings, there's been a number of testimonies
3 describing the loads associated with 903 and other
4 aircraft that we were aware of that were either in
5 limit or higher, and what we had determined in the case
6 of 903 and we had close coordination with American
7 Airlines and Airbus throughout this, we had determined
8 that that aircraft had seen above ultimate loads, but
9 it had seen above ultimate loads to an unknown level,
10 and I think this morning, you saw what was shown, that
11 it was only a guesstimate as to how high the loads had
12 gotten.

13 Now, if you go back to the incident in 1991
14 which is the only other aircraft in these group of
15 aircraft that have been discussed and studied and
16 supporting that AD, that particular aircraft saw just
17 about ultimate load. The Interflug incident. Now, the
18 difference between the two in terms of one being
19 considered acceptable for airworthiness and the other
20 one not is in the case of the Interflug accident, we
21 had two pieces of information. One was that the
22 highest load seen on that aircraft was just very
23 slightly above ultimate. The other was that there was
24 no NDI indication of damage.

25 Now, if you would go into Airbus's

1 certification databases, they had demonstrated that an
2 aircraft could take the equivalent of two lifetimes,
3 including load enhancement factor and double sequence
4 of ultimate load, one after the first lifetime, take it
5 for another lifetime and still be able to carry
6 ultimate load. That gave us confidence that that tail
7 could survive an ultimate incident in 1991 and fill out
8 its entire life.

9 In the case of the accident in 1997, because
10 we had an unknown load level that, as a conservative
11 approximation could have been within one percent of
12 failure. The decision was made that we do not have a
13 database where that tail had been loaded to within one
14 percent of failure and then taken for a lifetime's
15 worth of load, and so the decision was made to remove
16 it from service.

17 From what I understand, it's still available
18 to us in the investigation and we can further study the
19 effects of whatever was created in the 903 incident on
20 retained residual strength and cyclic loads or whatever
21 we desire.

22 MR. MURPHY: There's another series of ADs
23 and the NDI inspections were required on the 319 and
24 the 320 and the 321 aircraft as well as the 330
25 aircraft in this past year.

1 Could you give me the history behind the
2 reason for that NDI and those ADs?

3 DR. ILCEWICZ: Those ADs come back to this
4 phenomena that I referred to as weak bond previously.
5 What had happened was there was mistakes made within
6 the Airbus factories in -- in the materials used to
7 manufacture the fin boxes on those aircraft and the --
8 the particular material in question was a peel ply
9 which had release agent with it and that brought
10 contamination to those bond lines.

11 The whole problem, as I had stated before, is
12 not something that you can rely on factory NDI to
13 catch. It's a contamination that we have put or relied
14 in the composite industry on rigorous quality controls
15 of the materials that are used and if somehow a problem
16 still occurs, as it did in this case, there's a fail
17 safety designed into the aircraft, such that it could
18 accept large disbonds with those contaminated surfaces
19 and still maintain limit load.

20 Those ADs were initiated by service bulletins
21 by Airbus because their quality assurance did catch the
22 problem, although the catching of the problem occurred
23 after airplanes were put in service, and so they
24 immediately sent out service bulletins stating the
25 concern and a need to take all surfaces in question to

1 a bolted repair within a stated amount of time and
2 right on the heels of those service bulletins came
3 Airworthiness Directive equivalents from the French
4 side and then the U.S. side.

5 As far as this problem goes, the FAA's been
6 very active in -- in long-term solutions to deal with a
7 potential for "peel ply materials" to make it into the
8 production and be used improperly as in this case, and
9 since the time of -- of this occurrence and other known
10 events with other airplane manufacturers, we've done
11 research ourselves to work with the material suppliers,
12 get their product labels changed and make sure that
13 those types of materials aren't used in production or
14 -- or ever allowed to get to production.

15 MR. MURPHY: Okay. Had you said that they'd
16 all already been repaired?

17 DR. ILCEWICZ: Those aircraft have all been
18 repaired at this point in time, I think, as of, oh,
19 half to three-quarters of a year ago. So, the ADs
20 themselves are obsolete. Within the ADs, it called out
21 a need to perform NDI and -- and in a given amount of
22 time go all the way to these bolted repairs, and so
23 both were expected. The airlines and most airlines
24 looked at that and said we're going to bypass the need
25 for the NDI and avoid the cost of that and move

1 directly to the bolted repair.

2 MR. MURPHY: One last question. It was only
3 -- it was really only added because of the last exhibit
4 that was added at the pre-hearing conference from
5 American. So, what's being done with industry,
6 government and government groups to -- to standardize
7 maintenance procedures for composite aircraft
8 structures in the areas of inspection and repair?

9 DR. ILCEWICZ: In roughly 1990, composites
10 had been in -- in use for on the order of 10-15 years
11 and there had already been accumulated a significant
12 understanding of where issues and concerns were in
13 terms of standardization and use of common materials
14 between the major manufacturers and, you know, things
15 that were of concern to all the airlines that they
16 wanted to try to standardize and so the FAA initiated
17 an activity together with OAMs and all the major
18 airlines and it's an open activity through SAE. It's
19 referred to as the Commercial Aircraft Composite Repair
20 Committee, and in that organization, for the last 10 to
21 12 years, there's been very close coordination on a
22 number of working groups and things that need to be
23 standardized, and we support that to -- to a large
24 extent with our -- our workforce coming to the meetings
25 and making sure that there's a regulatory voice in the

1 directions that they go in their standards, and in --
2 in addition to that, there's another organization that
3 I am co-chairman for, called MIL Handbook 17, that was
4 referred to earlier, and again that's an international
5 organization.

6 It has a supportability side to it that's
7 coupled with the CACRC activities, and what the goals
8 of both those organizations is to -- to move to common
9 practices and be in position for these increased
10 applications of composites that appear on the horizon.

11 MR. MURPHY: Thank you very much, Dr.
12 Ilcewicz.

13 Madam Chairman, that concludes my questions.

14 ACTING CHAIRMAN CARMODY: Thank you.

15 Are there other questions from the Technical
16 Panel for the witness?

17 (No response)

18 ACTING CHAIRMAN CARMODY: All right. Moving
19 then to the parties, I will start with the Airbus. Oh,
20 I'm sorry. One more question from the Technical Panel,
21 Dr. Kushner.

22 DR. KUSHNER: Yeah. Hi. Thank you.

23 Are composites typically stronger in tension
24 or compression?

25 DR. ILCEWICZ: Composites are traditionally

1 known to be stronger in tension than compression,
2 although you can find examples where that's not always
3 true, depending on specific design detail and design
4 considerations.

5 DR. KUSHNER: Okay. And from a certification
6 perspective, you talked about the building block
7 approach. What are the things that you looked at as
8 you move up each level to show consistency with what
9 was learned at the lower levels?

10 DR. ILCEWICZ: It's not a highly complicated
11 activity. The programs that are most successful have a
12 very close association between what goes on in the
13 factory and what goes on in structural substantiation,
14 such that those two groups are -- are coordinated very
15 closely how it all comes together.

16 At the lowest stage, you're wanting to ensure
17 that you've got proper material controls because those
18 are usually the types of tests that you use to prove
19 variance with the material coming into your house for
20 production.

21 At the next highest levels, there is design
22 details that are common of a lot of the acreage areas.
23 Most areas have to have allowances for repair, have
24 some form of bolted joints. There's a lot of
25 stiffening elements that will look at crippling and

1 other modes of failure, and so there's quite a bit
2 populated at that level, and usually what would be done
3 is, you know, some portion of that would form an
4 additional statistical basis for design values, and
5 anything that's done at higher levels where it's not
6 practical to generate a whole lot of repetitive
7 testing, you will normally take a conservative approach
8 based off of whatever's generated at lower levels that
9 has the closest failure mechanism to what's being
10 observed at the higher levels.

11 DR. KUSHNER: Thank you.

12 ACTING CHAIRMAN CARMODY: All right. Moving
13 then to Airbus, Dr. Lauber?

14 DR. LAUBER: Madam Chairman, Airbus has no
15 questions for Dr. Ilcewicz.

16 ACTING CHAIRMAN CARMODY: All right.
17 American, Mr. Ahearn?

18 MR. AHEARN: Thank you, Madam Chairman.

19 Just a couple, Dr. Ilcewicz. Prior to the
20 587 accident, had you ever seen a composite lug joint
21 of this size in an aircraft application?

22 DR. ILCEWICZ: Not -- not in the detail that
23 I have since. I was aware that these existed on Airbus
24 aircraft and so I was aware just from being in the
25 industry.

1 MR. AHEARN: Do you have any sense of, with
2 your experience, as to how you would describe the
3 application?

4 DR. ILCEWICZ: The application, from what I
5 understand, was something that was done over a long
6 period of time with careful judgment by all parties
7 involved on, you know, what is the right way to design
8 a structure of that character and it's every bit as
9 comprehensive as what you would find for lugs in metal
10 structure, plus some additional conservatism.

11 MR. AHEARN: Okay. Let me -- let me draw
12 upon some experience that you've had in your previous
13 life at Boeing, if you will. You've seen single point
14 or single load points as you see in the Airbus and
15 you've seen the fastener patterns used with smaller
16 fasteners or small lugs.

17 In your estimation, which do you believe are
18 more -- or which efficiently more distribute load?

19 DR. ILCEWICZ: We get into a design
20 philosophy, especially going into my past experiences
21 with the Boeing Company. I'm not allowed to get into
22 that type of a discussion. I hope you would understand
23 that my past background at Boeing is --

24 MR. AHEARN: Certainly.

25 DR. ILCEWICZ: -- supposed to have been left

1 behind.

2 MR. AHEARN: Okay. Let's move on. You've --
3 I believe you were here earlier for the previous
4 witness testimony, Mr. Rackers, and you've heard
5 testimony about the design of the lugs to match the
6 pre-existing attached clevises. You also heard him
7 state from a designer's perspective, you could build it
8 stronger.

9 Do you believe there's an advantage or
10 disadvantage when you design to a pre-existing
11 attachment clevis design scheme as they did with the
12 B2B4 to the 310-300?

13 DR. ILCEWICZ: I think if you were to look
14 into the details of that and the next witness is going
15 to be the best one to answer that specific question,
16 you may realize that if they were to change the design,
17 it may even go in the other direction in terms of what
18 they had to do in order to make sure that it still had
19 the same geometry and ended up leading to margins that
20 were quite substantial in the case of that lug.

21 MR. AHEARN: Okay. Well, then I'll -- we'll
22 defer that question for Dr. Winkler.

23 Those are all the questions I have, Madam
24 Chairman.

25 ACTING CHAIRMAN CARMODY: Allied Pilots,

1 Captain Pitts?

2 CAPT. PITTS: Yes, ma'am. Thank you.

3 Good afternoon, sir. Earlier, you made the
4 statement, Airbus is on the conservative low end of the
5 composite standards. I didn't understand what you
6 meant by that. Could you expand on that?

7 DR. ILCEWICZ: I believe the question related
8 to what design strain levels is the structure being
9 worked to, and usually when you use that kind of
10 terminology, you're talking about the structure away
11 from concentrated attachment points or access holes.
12 You're talking about structure that's the acreage-type
13 structure and that structure usually gets driven by
14 compression and -- and oftentimes that compression
15 shear interaction because there's a torque on a torque
16 box together with the fully reversed loads on either
17 side of the fin can be tension or compression, and so a
18 design strain level to deal with impact damage on
19 different panels usually becomes one of the design
20 drivers for an aircraft structure and the strain level
21 that they were applying in their case is -- is quite
22 low relative to other that I'm sure they have pursued
23 over time as well as any other structure that we're
24 seeing out in service.

25 CAPT. PITTS: Then does that relate to an

1 overall lower capability to --

2 DR. ILCEWICZ: No. That's what I was hoping
3 that -- lower design strain levels mean, you know,
4 again let's -- let's go back to a curve of, you know,
5 what -- what strength you're expecting out of this
6 structure. If you make the strain level that you apply
7 for design ultimate load, let's say a 0035 or something
8 like that or 0032 or whatever, then the limit strain
9 level's going to be, you know, a 1.5 division off of
10 that. If you were to apply a higher design strain
11 level for ultimate, let's say a 004 or 005, then the
12 strain level that you would be working the structure at
13 at limit load would be higher still and everything
14 tends to go up, including the strain levels. You're
15 working fatigue loads on the structure, too.

16 CAPT. PITTS: Okay. Thank you for clarifying
17 that.

18 I'd like to talk about this limit load value
19 just a little bit.

20 DR. ILCEWICZ: Sure.

21 CAPT. PITTS: And I understand that you're a
22 materials and structure expert, not necessarily a
23 regulatory expert, but you do speak for the FAA. Now,
24 the FAA takes a systems safety approach to design of
25 equipment, and I'd kind of like to frame the question

1 in that light.

2 Now, just for the edification of all, in a
3 systems safety approach, we're going to consider the
4 design concept, the design itself, the operation. It's
5 cradle to grave. Is that your understanding?

6 DR. ILCEWICZ: Correct.

7 CAPT. PITTS: We look at it in operation.
8 So, we've heard a lot about this limit load and that it
9 has -- was designed to a value and it met the standard.
10 Now, in reviewing that, it speaks to when designing an
11 aircraft, it is necessary to determine the highest load
12 that can be expected in normal operation under various
13 operational situations.

14 Now, you have a design in operation and now
15 you become aware of the fact that in your normal
16 operation -- operational conditions, you're exceeding
17 limit load, and it's not one of your examples, but I
18 think you probably -- one of your exhibits, but I think
19 you probably saw the -- the citations in -- in 7Q, I
20 believe it is, where there's seven examples of this
21 design exceeding limit load.

22 Now, once we are aware of that in an
23 operational end use in-service sort of perspective,
24 where are we relative to the -- to the FARs and meeting
25 the regulatory spirit and intent? In other words, we

1 are exceeding limit load in normal operations or under
2 various conditions. What's supposed to happen?

3 DR. ILCEWICZ: Well, I'm going to have to
4 take the -- the discussion back to my world of
5 expertise which is going to be safety and relationships
6 in the composite world. Much of your question is -- is
7 focused on loads, and so I'm going to leave that
8 behind, but nevertheless, one of the reasons why we
9 designed structure to be good to limit times 1.5 is
10 because we realize that there can be anomalous events
11 that would take us both limit load. That's one of the
12 reasons. There are many other reasons.

13 Brian has asked me a series of questions as
14 to why we do ultimate static strength substantiation,
15 why we also do damage tolerance. Those two tend to
16 balance things, and if I ever try to explain what I'm
17 doing to my children, what -- what I'll sometimes try
18 to do, you know, in that analogy is I look at ultimate
19 load as an extremely essentially near-impossible load
20 level, you know, per the way that the structure has
21 been designed because it's a 1.5 factor off of the
22 highest load expected.

23 Now, for that, I want to be good for damages
24 that are possible in service because I'm getting safety
25 out of this factor of safety. Now, in the case of --

1 of limit load, we know that there are anomalous events
2 or -- or damage states that can occur which is why we
3 inspect airplanes in general that can degrade the
4 strength occasionally below ultimate, so that that full
5 factor safety is not achieved on, you know, individual
6 case-by-case rare events, but we still want to maintain
7 a limit load capability or a certain amount of fail
8 safety, you know, going back to old language, for those
9 rare damages that may degrade strength to that level
10 because that is closer to what is expected in service.

11 CAPT. PITTS: Right.

12 DR. ILCEWICZ: And so, those two tend to be a
13 balance. In both cases, you're getting safety out of
14 still being good for extremely rare events.

15 CAPT. PITTS: I followed your discussion in
16 terms of damage, but in an undamaged structure,
17 operationally in use, service record shows that the
18 value used to determine the limit load is being
19 exceeded. What would be the intent of the regulation
20 at that point?

21 DR. ILCEWICZ: The -- the definition of limit
22 has been changed from a structures analyst perspective,
23 and we have not designed the structure to accommodate
24 for that, and so it's hard for me to answer your
25 question without going into an area that -- that I am

1 not a specialist in.

2 CAPT. PITTS: I understand. Well, since the
3 expectation of the limit load is the highest load
4 factor that we expect to see and we do in fact then
5 begin to see it in operational service, as a structures
6 expert, would that not cause you to begin to reconsider
7 whether that load, that load limit value is accurate?

8 DR. ILCEWICZ: Again, you're asking me to --
9 to try to influence things that are out of my control
10 and expertise, and I don't care to comment on that.

11 CAPT. PITTS: And so, from your review of it
12 with your structural perspective, if field service
13 information came to you that -- that highlighted
14 exceeding limit load, you would consider that outside
15 of your expertise to comment on in relationship to
16 ensuring the airworthiness of a structure?

17 DR. ILCEWICZ: Well, from what I know and
18 what we do in composite structure, I have confidence
19 that a large majority of the composite structure out
20 there maintained properly would still be in good shape.

21 We don't have known fatigue damage growth mechanisms
22 for the strain levels we operate at. So, that becomes
23 something that gives me a certain amount of confidence.

24 However, it's still something that being outside the
25 design envelope is something that, as a stress analyst,

1 it makes me uncomfortable, and I would like to see the
2 investigation move in the directions such that we solve
3 that problem and we don't have that occurring to
4 aircraft.

5 CAPT. PITTS: All right, sir. How many times
6 have you seen load limit exceeded in an aircraft
7 structure?

8 DR. ILCEWICZ: Well, I believe looking at the
9 issues of limit load through my experiences in the
10 industry, occasionally that can be exceeded and it's
11 usually an event that has brought attention to the
12 operations people, the crew, and they will react to
13 that and it will be reported and dealt with
14 accordingly.

15 CAPT. PITTS: Would that include such things
16 as identifying a prohibited maneuver or a system
17 operating limitation, that sort of thing?

18 DR. ILCEWICZ: I would not be able to answer
19 that from my background.

20 CAPT. PITTS: All right, sir. I'm going to
21 shift the questions. I have two final questions.

22 In high load conditions, do loads
23 redistribute in the metal assembly like they do in a
24 composite assembly? You may have already answered
25 that, but I -- I didn't -- didn't stay sharply focused

1 there.

2 DR. ILCEWICZ: When -- when you look at the
3 way in which metals fail and composites fail, a
4 fundamental difference exists in that metals will start
5 to yield and move towards a strain hardening phenomena,
6 whereas in composites, they start to fail and they move
7 towards the strain softening behavior, and I realize
8 that different words are often used for that, but
9 fibers will start to break, the weakest fibers.
10 Delaminations and matrix cracking will occur and that
11 effectively softens the zone immediately adjacent to
12 where the high stress is coming from. That softening
13 is something that behaves somewhat in the same
14 characteristic as a yield zone in metals, although the
15 characteristics are -- are uniquely different in
16 composite, not sensitivity, can be distinctly different
17 than metal.

18 So, for example, in metals, they're more
19 concerned with the sharpness of the defect in a crack,
20 whereas in a composite, if it's a hole or a crack,
21 there doesn't tend to be much difference because the
22 softening tends to create much the same redistribution
23 and behavior.

24 CAPT. PITTS: All right, sir. Thank you.

25 And this final question, calling upon your

1 entire experience in the aviation industry, not
2 specific to any employer. In your experience, how
3 common is it for a vertical stabilizer to exceed the
4 ultimate loads in operation?

5 DR. ILCEWICZ: Before this accident, I was
6 unaware of that ever occurring.

7 CAPT. PITTS: So, when choosing ultimate in
8 the future, should it be higher -- a higher standard
9 for composites, in your opinion?

10 DR. ILCEWICZ: I don't believe that has any
11 association. Composite is -- is not the function that
12 relates to higher loads.

13 CAPT. PITTS: It's -- the concern would be
14 the -- the loads of the composites were designed to --
15 to meet?

16 DR. ILCEWICZ: Right.

17 CAPT. PITTS: All right, sir.

18 DR. ILCEWICZ: If you -- if you take metal or
19 composite well above limit loads, you -- depending on
20 your design, you're moving outside the design envelope
21 in both cases, regardless of what the material is.

22 CAPT. PITTS: All right. Thank you very
23 much, sir.

24 Thank you, ma'am. I have no further
25 questions.

1 ACTING CHAIRMAN CARMODY: The FAA, Mr.

2 Donner?

3 MR. DONNER: Thank you, ma'am. Once again,
4 no questions.

5 ACTING CHAIRMAN CARMODY: Yours have all been
6 asked, I believe.

7 Anything from the Board? Member
8 Hammerschmidt, questions?

9 MEMBER HAMMERSCHMIDT: No questions.

10 ACTING CHAIRMAN CARMODY: Member Goglia?

11 MEMBER GOGLIA: I just have one question.

12 I'm curious. Have you ever seen -- I'll use
13 the term that we -- we would use on the ramp all the
14 time -- wrinkled skin on the airplane?

15 DR. ILCEWICZ: Yes.

16 MEMBER GOGLIA: Are you familiar with that
17 term?

18 DR. ILCEWICZ: Yes.

19 MEMBER GOGLIA: And in my past, I've seen
20 airplane fuselages with severe wrinkled skin. Where do
21 you think that would fit on this load -- in these loads
22 categories we're talking about, design load, limit
23 load, ultimate load? Was it approaching ultimate load?

24 DR. ILCEWICZ: Conceivably, it's -- it's
25 above limit and approaching ultimate, right. The

1 regulations require that the structure can accept limit
2 load and not permanently deform. In the composites
3 world, we don't want to see matrix cracking occurring
4 at that level or any permanent set occurring.

5 MEMBER GOGLIA: Okay. Thank you.

6 ACTING CHAIRMAN CARMODY: And Member Black?

7 MEMBER BLACK: Just a quick one. As a B-52
8 maintenance officer, believe me, I've seen wrinkled
9 skin.

10 The -- I guess this question might not --
11 might be out of your area since you're primarily, it
12 sounds like, a design person, but do you believe we
13 have adequate tools and technology to conduct periodic
14 maintenance and inspection after events on composite
15 materials in the industry in the United States?

16 DR. ILCEWICZ: Yes, I believe we do. One of
17 my job functions is as the world of composites
18 continues to evolve and it will, there's -- there's
19 little doubt of that from where I sit, I've got plenty
20 of work on my plate, that I have to continue to stay on
21 top of new technology in the manufacturing and
22 materials world and ensure that I understand for these
23 advances what are the most critical defects and how can
24 they be detected in service, and the way that I've
25 approached that, together with the FAA Composite Team

1 of people that I work with closely, is to make sure
2 that we're in close cooperation with airlines and
3 operators and be in a position where everything and
4 anything that is found is brought to our attention and
5 it's recognized, such that we can apply that to the new
6 technologies and make sure that it isn't an Achilles
7 heel. It's not being considered in design.

8 MEMBER BLACK: Thank you.

9 ACTING CHAIRMAN CARMODY: Mr. Goglia?

10 MEMBER GOGLIA: I'd like to go back to follow
11 on to that. I have -- I have a concern in my own mind.
12 When I put myself back in the ramp and I think about
13 the American Airlines 903 airplane, we now know, we now
14 realize this airplane exceeded -- moved out into
15 territory that was unknown.

16 How are we supposed to -- we, the
17 maintainers, we, the engineering department, how are we
18 supposed to know in composites that we've moved off
19 into this area? I touched on it just a little bit.
20 The wrinkled skin is always a good clue in conventional
21 airplanes that you've done something that you shouldn't
22 have done.

23 DR. ILCEWICZ: Right.

24 MEMBER GOGLIA: You know, how are we going to
25 maintain airworthiness in the fleet, you know? Mr.

1 Charbert, you and I have in different roles, we have
2 the job of ensuring airworthiness.

3 How are we going to ensure airworthiness when
4 we can have damages to composites or other new
5 materials that remain unseen and we don't have the
6 ability to determine if they've gone over a certain
7 threshold?

8 DR. ILCEWICZ: Well, John, I think that the
9 best way for that and usually when you get to the
10 "wrinkled skin condition" or the gravel example of the
11 large concrete, there's at least some visual
12 indications of something occurring, but in the case of
13 903, that went to very, very high load levels without,
14 you know, a visual bend or deformation, and in that
15 particular incident, there was an accident. In fact, a
16 passenger was seriously injured, and what we know today
17 in terms of extreme lateral loads, I've got extreme
18 confidence that an event like that would never occur
19 again without there being a thorough inspection before
20 that airplane is put back in service.

21 Similarly, the other case of getting such
22 high loads, the Interflug incident was a very severe
23 ride. I've seen the simulations of it and it was
24 intense in terms of what the passengers went through.
25 So, we knew that happened from an operations

1 standpoint, but there has to be the communication and
2 the realization that, all right, I have exceeded my
3 design envelope and now I'm out of the world of
4 scheduled maintenance and I'm into the world of
5 unscheduled maintenance, and the only way that comes is
6 through close communication like we're doing in the
7 CACRC with the maintenance people but also the
8 operations people, so that if somebody drives a service
9 truck into the side of a composite aircraft and gets
10 out and, you know, realizes he hit it pretty good, that
11 he's not in a position where he just turns around and
12 walks away without letting people know that that has
13 happened and so that it can be dealt with accordingly.

14 MEMBER GOGLIA: You kicked over a can of
15 worms with that one. Given -- given the state of
16 airline management today, actually because of their
17 discipline policies, they actually encourage what you
18 just said. Somebody, especially a baggage -- ramp
19 service man, third party provider for services, would
20 take a look at the airplane and say, well, yeah, I hit
21 it but it's not damaged, and I'm not turning myself in
22 and take the punishment.

23 DR. ILCEWICZ: Well, that's -- that -- that
24 is why in our "threat assessment", we hammer on these
25 things until visibility is evident, but in -- in the

1 case of something such as that, we also install what we
2 refer to as fail safety which, once you got into a more
3 detailed inspection, even if they want to believe that
4 it's not there, we still have fail safety and we still
5 have sufficient damage tolerance to survive those types
6 of events and still carry the loads.

7 MEMBER GOGLIA: What has changed today that
8 would make the 903 event rise to the surface before the
9 airplane was returned to service? Are we -- are we
10 going to pull the flight data recorder after every
11 report of turbulence event and wait until it's analyzed
12 at some distant location before we return it to
13 service?

14 DR. ILCEWICZ: Well, in the case of those
15 specific airplanes, there's an airworthiness directive
16 that's been active since March and this whole purpose
17 of that was not only to catch things of the magnitude
18 of 903 but things conservatively less than that, and in
19 all of the inspection that was performed to support
20 that activity, we understood that that was a
21 conservative lower limit that we've put into that
22 airworthiness directive.

23 MEMBER GOGLIA: And in that, I have not seen
24 the AD.

25 DR. ILCEWICZ: It's one of the exhibits.

1 It's called "Extreme Lateral Loading".

2 MEMBER GOGLIA: Okay. I have seen the
3 heading.

4 ACTING CHAIRMAN CARMODY: Is there another
5 question or are we having a conversation?

6 MEMBER BLACK: I would look at it carefully.
7 Are we doing that on all composite tail airplanes or
8 just the Airbus 300-600?

9 DR. ILCEWICZ: The AD is directed at the
10 A300-600 because of the history that was uncovered in
11 our investigation with Airbus.

12 MEMBER BLACK: So, that means if we had a 777
13 that was involved in some sort of a lateral event or a
14 yaw event, we wouldn't look at it?

15 DR. ILCEWICZ: I don't believe that's the
16 case. I believe the 777 is also familiar with this
17 accident or any of the events surrounding this accident
18 and it is understood within the aviation community.
19 The key is that when you've taken things outside of the
20 design envelope, that that falls under descriptions
21 that relate to unscheduled maintenance and that type of
22 -- of loading event is something that maintenance
23 manuals will acknowledge and bring forth an
24 investigation and communication with the OEMs on it.

25 ACTING CHAIRMAN CARMODY: Thank you for your

1 response.

2 Is there anything else from the Tech Panel?

3 Any questions of this witness?

4 (No response)

5 ACTING CHAIRMAN CARMODY: How about the
6 parties? Any questions from any of the parties of this
7 witness?

8 (No response)

9 ACTING CHAIRMAN CARMODY: Well, then our
10 thanks, Dr. Ilcewicz. I'm sorry for mispronouncing
11 your name. Thank you for your testimony. It was
12 excellent and you made things very clear for us.

13 (Whereupon, the witness was excused.)

14 ACTING CHAIRMAN CARMODY: Why don't we just
15 take a short break, maybe 10 minutes, and then we'll
16 have Mr. Winkler next.

17 Thank you.

18 (Whereupon, a recess was taken.)

19 ACTING CHAIRMAN CARMODY: Ms. Ward, would you
20 proceed with the next witness, please?

21 MS. WARD: I'd like to call Mr. Erhard
22 Winkler and to assist him with translation will be Mr.
23 Rackers. Please raise your right hand.
24 Whereupon,

25 ERHARD WINKLER

1 having been first duly sworn, was called as a witness
2 herein and was examined and testified as follows:

3 MS. WARD: Thank you.

4 Mr. Winkler, could you please state your full
5 name, your present employer, and your business address?

6 MR. WINKLER: Yes. My name is Erhard
7 Winkler. I am employed at Airbus Hamburg, Airbus
8 Germany in Hamburg.

9 MS. WARD: And what is your present position,
10 and how long have you been in that position?

11 MR. WINKLER: My current position is
12 Composite Specialist, and I am in this position since
13 middle of last year.

14 MS. WARD: Could you briefly describe your
15 duties and responsibilities and any education and
16 training that you have received to qualify you for this
17 position?

18 MR. WINKLER: Yes. My duty is -- is
19 technical advisory to Composite Development in Germany
20 for Airbus, and I started working for Airbus in 1976 as
21 a stress engineer, and I was directly in composite
22 research. In 1978, I became a member of the
23 Development Team of the A310 and A300-600 composite
24 tail development up to 1985. I was during this time
25 responsible for the finite element analysis and also

1 for the test principles, including the full-scale test.

2 From 1985 up to 1995, I was responsible for
3 analysis method for composite materials and also
4 involved in the development for the vertical tail for
5 the A320 and A340. In 1995, I became a team leader for
6 the development of the new fin for the A330-200 and my
7 responsibility was the full justification of the
8 structure, including the certification.

9 In 1998, I became a team leader -- sorry.
10 Department leader for the rear fuselage and fin, and in
11 this position, I was responsible for the development of
12 the rear fuselage, including the rear pressure bulkhead
13 from composite materials and the fin for the A340-500
14 and 600.

15 MS. WARD: Could you also state your
16 education?

17 MR. WINKLER: Pardon?

18 MS. WARD: Your education?

19 MR. WINKLER: My education is I have a
20 Master's Degree in Aeronautical Engineering from
21 Technical University in Braunschweig, Germany.

22 MS. WARD: Thank you, Mr. Winkler.

23 Madam Chairman, I find this witness qualified
24 and now pass it over to Mr. Brian Murphy for
25 questioning.

1

2

EXAMINATION

3

4

MR. MURPHY: Still good afternoon. I don't have to say evening.

5

6

7

8

9

10

11

12

13

Good afternoon, Mr. Winkler. I'd like to discuss the -- is this -- can you hear me? The following topics with you. The design and construction of the -600R vertical stabilizer and rudder, the certification of the vertical stabilizer and rudder, NDI and visual examinations, the 587 and 903 structural assessments, and then Dr. Fox would like to speak to you about the fracture features of the accident lugs and some -- some test lugs, I believe.

14

15

16

I also -- Madam Chairman, Mr. Winkler has also prepared some overview material and he'd like to present that for us at this time.

17

18

19

20

21

22

23

ACTING CHAIRMAN CARMODY: Yes, please.

MR. WINKLER: I would like to -- like just to present an overview on the vertical tail design, the certification approach, inspection procedures, then something about the participation of the investigation of the accident concerning structure, and will finish with a structure overview and a general summary.

24

25

The most important thing for an aircraft structure is that it is strong enough to resist all

1 load conditions as required by the FAR-25. Because the
2 vertical stabilizer is fabricated from composite
3 material, compliance has to be provided according to
4 the guidance material AC-20107-A which is related to
5 the application of composite materials for primary
6 aircraft structures.

7 The structural design and the sizing process
8 depends on the load conditions. The loads analysis
9 provides loads envelopes for lateral maneuver and gust
10 at certain sections along the span of the vertical tail
11 in terms of shear force, bending moment and torsion
12 moment. The figure shows the envelope and peaks over
13 M_z at the root of the fin. For selected conditions,
14 the Loads Department provides then the aerodynamic
15 pressure and the inertial loads distribution in chord
16 and span-wise direction which is then used on the
17 finite element model to calculate the interior loads.

18 The response to these external loads which
19 are -- sorry -- which are composed from aerodynamic
20 loads and inertial loads are applied to the -- to the
21 fin box and is causing interior loads in terms of
22 contention and compression loads on the skin panels,
23 including shear, and on the other side, an example is
24 shown for -- including the spar caps.

25 At the bottom of the fin, these interior

1 loads are reacted to the fuselage. This is shown on
2 the left-hand side, bottom left-hand side in terms of
3 the lateral load F_y and two components, normal to -- to
4 in direction of the flight direction, F_x , and normal to
5 the plane which is given by F_x and F_y in direction of
6 F_z , and additional two moments of around the X_z and the
7 X .

8 The fin and rudder design. The fin -- the
9 vertical tail is composed from the rudder and the fin
10 box. The fin box is the major part which transmits the
11 loads from the rudder via the box to the fuselage. The
12 fin box itself is a monolithic structure assembled from
13 two skin panels, 18 ribs, and three spars. The skin
14 panels are composed of skin panel of -- of laminate
15 which is reinforced for bending stiffness by 24
16 stringers of double-T section.

17 At the lower end of the skin panels on each
18 side are six attachment -- on each side are three
19 attachment fittings and some six arranged to be
20 attached to the fuselage. The rudder is a sandwich
21 construction which is assembled from a left-hand side
22 and the right-hand side flat skin panel and the front
23 spar which builds up a triangular section which is
24 closed on top and bottom by ribs. It has a leading
25 edge, an additional tip, and seven hinge fittings from

1 aluminum alloy.

2 Concerning the design, the structure, the
3 skin has no unusual features, and from -- therefore, it
4 represents the state of the art concept. The fuselage
5 attachment fittings at the lower end of each skin
6 panels are composed from an interlock and an outerlock
7 which is bonded together by the wet skin during the
8 autoclave process. These fittings provide the
9 necessary strengths for the attachment of the fin to
10 the fuselage and fabricated from more than 200 plys
11 each. They provided smooth transition of the
12 attachment loads to the reinforced skin.

13 The certification basis of the structure is
14 FAR-25 for the rudder up to Amendment 41, including the
15 Amendment 45, for the Damage Tolerance Paragraph 571
16 and the Advisory Circular from the FAA, AC-20107 in the
17 first edition from 1978. For the fin box, the FAR
18 requirements are up to Amendment 44, and for related to
19 composite material, we have to apply the STPA Note,
20 Technique 1804, Edition 2, which is the European
21 equivalent at that time for the FAA Advisory Circular
22 20107-A from the first revision from 1984.

23 The design of the fin box and the rudder of
24 the A300-600 meets or exceeds all certification
25 standards in both -- in the United States and Europe.

1 After the harmonization of the certification standards
2 in 1981, subsequent type certifications through joint
3 U.S. and European processes has been done since this
4 period.

5 The certification of the composite structure
6 has been validated by over 40 million flight hours of
7 experience by Airbus aircraft. The certification is
8 mainly supported by the structural testing. We have
9 seen this testing pyramid before in the presentation of
10 Bernd Rackers. The upper part is related to non-
11 generic specimens which are directly linked with the
12 design of the A300-600 vertical stabilizer. The
13 detailed tests and subcomponent tests are used to
14 generate design allowables and also to validate finite
15 element calculations which are compared with the
16 measurements during the subcomponent testing.

17 The proof of structure is based mainly on
18 design criteria which are locked to assure the
19 structure -- that the structure will withstand all
20 critical environmental conditions, and we have chosen
21 loads design strain level in order to minimize the
22 impact damage effects. The static proof of structure
23 has been done by demonstrating ultimate loads, taking
24 into account the most adverse environmental conditions.
25 The ultimate loads have been tested after fatigue

1 loading and the test article includes impact damage up
2 to the visibility threshold and it has been shown that
3 the structural strength has not been degraded below
4 limit -- ultimate load requirement.

5 The proof of structure fatigue damage
6 tolerance has been done -- has been demonstrated
7 through testing with artificially-damaged structure,
8 including manufacturing anomalies and in-service
9 damage. Permitted manufacturing anomalies and
10 accidental in-service damage do not propagate in
11 fatigue and this called the no-growth concept.

12 The full-scale test is divided into two
13 sections, the fatigue justification and the damage
14 tolerance justification. Both sections were done by
15 cycling of a wet structure in an environmental chamber.

16 The first what has been applied were tolerability
17 defects at artificially-damaged and repaired solutions
18 to the test article. After doing this, a pre-test to
19 80-percent limit load has been performed and the
20 cycling after 49,600 flights which was finished with
21 the stiffness check to compare with the finite element
22 calculations. Then we have further cycling up to
23 67,600 cycles which was conducted under hot wet
24 conditions and finished by an ultimate load test.

25 The next step was the introduction of very

1 large damage for the damage tolerance justification.
2 After the introduction of these large damage, visible
3 damages, we conducted a limit load test, and after
4 this, up to 120,000 cycles, the fatigue and damage
5 tolerance justification for this damage and also to
6 validate the no-growth concept.

7 At the end of this phase, we conducted an
8 ultimate load test under hot wet conditions. The
9 structure sustained these loads without damage and
10 after these tests, the discreet source demonstration
11 has been performed by introducing large damage caused
12 by auto burst. For this demonstration, we used 40
13 percent limit load for the gust condition and 70
14 percent for the lateral maneuver condition. This test
15 -- after these tests, the structure was repaired only
16 at the auto-burst damage, and the rupture test was then
17 conducted under hot wet conditions up to a level of 1.3
18 times limit load for corresponding to the loads from
19 A300-600R.

20 So, in summary, we have conducted two times
21 ultimate load test on the structure and several times
22 lower test for stiffness check and finally the rupture
23 test up to a level of 1.93 times limit load.

24 Concerning the discreet source damages, we
25 have two scenarios justified. The first one is the

1 single lug failure. This has been done by analysis and
2 by conducting supporting center lug test. For the
3 other conditions concerning the attachments, this has
4 been done by analysis and by using the achieved stress
5 level form of the full-scale test at 1.93 times limit
6 load.

7 For the APU auto burst scenario, an
8 artificial cut of about 14-inch length has been applied
9 at the upper center area designated with the .2.
10 There's a skin panel and a rear spar cap. The
11 structure's initial quality control is performed during
12 the manufacturing process until the delivery status of
13 the structure to assure that all parts have no
14 unacceptable internal anomalies. The in-service
15 inspection is -- takes only non-destructive testing
16 inspection into account for -- to assess any visible
17 damage or in case of the certificate loads are
18 exceeded.

19 The contribution Airbus did to the structural
20 investigation is mainly done by finite element
21 analysis. We are using this model, what is shown here.

22 It's a very detailed model which is able also to
23 address failure scenarios to the rudder because we are
24 able to predict attachment bolt loads on the fittings
25 which are attached at the rear spar and the spar of the

1 rudder itself. It is -- has 95,000 degrees of freedom
2 and is used to calculate the encountered load levels
3 which are provided by the Loads Department. We had
4 seen this picture in the morning from Mr. Curbillon.
5 We have certain scatter pattern of loads in which the
6 load level is -- has been calculated, and the four
7 conditions which have been analyzed are shown here by
8 the external loads, the bending moment, torsion moment
9 and the shear load, and for these four load cases, also
10 the resultant load, which is applied on the tail rear
11 right-hand center, the right-hand lug, on -- on the
12 accident aircraft is shown on -- in the lower -- lower
13 line, starting with 82 tons and ending up with nearly
14 95 tons. We can say that the computed loads from AA-
15 587 are at rupture level compared to the full-scale
16 test result.

17 I want now to finish with the structure
18 overview. The vertical stabilizer and rudder comply
19 with the requirements of FAR-25. We have shown,
20 demonstrated that non-visible damage will not call for
21 the operational life. We have also demonstrated that
22 visual inspection is appropriate because the structure
23 is designed with a very low design strain level, and
24 the outcome of the analysis concerning the accident is
25 that strains and forces calculated for AA-587 loads are

1 at the level of the rupture where you obtain from full-
2 scale test.

3 Concerning the other domains which
4 participated in the investigation, we have concerning
5 materials, there is no evidence up till now of material
6 deficiencies in the AA-587 fin. There is no evidence
7 of a system failure during the flight, and the fin has
8 tested up to a 193 percent of limit load which is well
9 in excess of the requirement, and the Flight 857 was
10 subjected to loads at rupture level.

11 Thank you very much.

12 MR. MURPHY: Thank you, Mr. Winkler.

13 Regarding the presentation, you mentioned
14 that you did the fail-safe analysis on the right rear
15 lug. Assuming the right rear lug failed and then
16 followed up with a subcomponent test on the center lug,
17 analytically, did you consider each lug failed
18 individually and worked through the fail safety
19 analysis?

20 MR. WINKLER: Yes. Yes, that was done. The
21 most critical situation for the failure of -- of the
22 rear lug.

23 MR. MURPHY: Okay. Thank you. That was the
24 decision for the choice. Thank you.

25 The slide that shows the four -- the four

1 load conditions that -- that were -- where loads had
2 been developed, have you had a chance to analyze all of
3 those conditions to date?

4 MR. WINKLER: Yes.

5 MR. MURPHY: Okay.

6 MR. WINKLER: We -- we applied this load on
7 our finite element load or do you -- do you reflect to
8 a special lug analysis?

9 MR. MURPHY: No. Just have you had a chance
10 to look at them with the finite element analysis?

11 MR. WINKLER: Yeah.

12 MR. MURPHY: Okay.

13 MR. WINKLER: The result of -- the resultant
14 load is the outcome of the finite element analysis.

15 MR. MURPHY: The resultant loads, yes.

16 MR. WINKLER: Yes.

17 MR. MURPHY: Okay. You haven't then -- what
18 I'm -- what I'm driving at is, it was stated earlier
19 that the Condition B-375 corresponds most closely to
20 the bang heard on the CVR according to Mr. Curbillon
21 and Mr. Kerlin, and what I was interested in is you
22 haven't done the detailed solid -- the exhibit is 7BB,
23 I believe, is your solid model, your solid detail.

24 MR. WINKLER: Yes.

25 MR. MURPHY: Have you had a chance to analyze

1 other load cases than those shown in the exhibit to
2 date?

3 MR. WINKLER: No. Up to now, not.

4 MR. MURPHY: No. Okay. And I'm correct in
5 assuming then that what your -- the plan will be to
6 analyze that at a future date and use that detailed
7 finite element analysis to correlate with the existing
8 subcomponent and full-scale tests that are available?
9 Data that is available? Okay.

10 You will use that model with the additional
11 load cases that have not been analyzed to date --

12 MR. WINKLER: Yes.

13 MR. MURPHY: -- to go back and compare with
14 your full-scale and subcomponent databases?

15 MR. WINKLER: That -- that is what we intend
16 to do with this model.

17 MR. MURPHY: Okay.

18 MR. WINKLER: We want to correlate. I think
19 the model is -- is so -- is capable to -- to -- to
20 analyze the -- the failure sequence of this lug, and we
21 want to compare the component test with the full-scale
22 test and also with the failure scenario on the 587 to
23 -- to -- to validate the -- the -- the load level is --
24 is at rupture.

25 MR. MURPHY: Okay. Regarding the design and

1 construction of the -- of the stabilizer and rudder,
2 there's been some discussion about the -- what the -
3 600R, 310-300, vertical fin was intended to be used
4 for. Was it ever intended to be used on the B2B4
5 aircraft?

6 MR. WINKLER: No.

7 MR. MURPHY: No. Okay. Got that cleared up.
8 Are the VTP and -- and -- I'm sorry -- the vertical
9 stabilizer and the rudder common to the -600R only?

10 MR. WINKLER: No. It's -- it's on the A310-
11 300 and on some other aircraft which were built after
12 -- after the certification of -- of the A300-310-300.
13 Because we stopped at a certain point, we stopped the
14 fabrication of metal fins, so there are some other 600-
15 type aircraft and 200 -- 310-200 aircraft which are
16 fitted with -- with these stabilizers.

17 MR. MURPHY: Okay. So, never for the B2B4
18 and maybe -- I believe it's all of the -600Rs have the
19 tail and then --

20 MR. WINKLER: Yes.

21 MR. MURPHY: -- all of the 310-300s --

22 MR. WINKLER: If you want to know the exact,
23 I have --

24 MR. MURPHY: Yes. If you have that, because
25 it's been a topic of discussion several times here

1 today.

2 MR. WINKLER: These are the aircraft which --
3 which differ from -- from the A310-300 and -- and A300-
4 600 which are fitted with -- with composite vertical
5 stabilizers.

6 MR. MURPHY: Really, it looks like nine plus
7 five, real quick. So, only 14 aircraft outside of the
8 300 fleet and the 600R fleet have -- have a composite
9 tail?

10 MR. WINKLER: Yeah. That's right.

11 MR. MURPHY: Okay. Could you provide a more
12 detailed description of the VTP, the fuselage-attached
13 structure?

14 MR. WINKLER: Yes, I can. I have some --
15 some slides, if it's --

16 MR. MURPHY: Whatever makes it easier.

17 MR. WINKLER: On this figure, you can see the
18 lower end of an A310-300 or maybe it's the same -- the
19 same fin also as applied on the 300-600, where you can
20 see the bottom closure rip and the lugs, the lugs which
21 are extending below this lower rip on both sides. That
22 is the front lug, center lug and the rear lugs, and
23 also the -- the lugs are -- the lateral shear lugs are
24 visible from the front spar, rear spar and center spar.

25 You see here a sketch of the rear lug. It's

1 -- you see it cross -- the cross section below that is
2 -- is a cut directly to -- through the skin and you see
3 the transition of -- of the outer and the inner pre-
4 cured lugs to -- to the skin. The main lugs are built
5 from two pre-cured multilayer composite parts which are
6 joined by a co-bonding process with a skin laminate
7 between and the stringer run out on the inside during
8 the autoclave processing of the integrated skin panels.

9 The shear fittings are built by reinforcing
10 the basic spar rep laminate with the variety of layers.

11 Each fitting has spherical bearings accommodate --
12 which accommodate the lateral yokes. The counterpart
13 in the fuselage is a forged aluminum alloy fork-headed
14 fitting which accepts the main lugs. The connection
15 between the fin and fuselage, main fittings is provided
16 by an expanded tapered bolt sleeve which is coated by a
17 bond layer. You can see on the bottom part of the
18 figure the components and on the top the assembled bolt
19 which is secured by castellated nut and the cotterpin.

20 The purpose of the fin to fuselage attachment
21 is to provide a reaction for the aerodynamic and
22 inertial and mass loads resulting from lateral gust and
23 maneuver inputs. The main lug also are transmitting
24 the loads equivalent to the bending moment, the
25 torsional moment, the skin panel shear flow and the

1 portion of the lateral shear. The lateral shear
2 fittings are transferring the majority of lateral shear
3 to the fuselage. The fin to fuselage attachment is
4 vertical over the determinate and therefore it provides
5 damage tolerance by load redistribution capability.
6 The structure accepts a single main lug failure up to
7 limit load level as defined for the intact condition.

8 MR. MURPHY: All right. You had described
9 the purpose of the lugs overall in reacting. The
10 global loads on the structure. If we get down to the
11 load -- the lugs themselves, what would be the
12 components of loads at each individual lug that would
13 be reacted?

14 MR. WINKLER: The main lugs are reacting
15 mainly the bending moment by -- by the load in that
16 direction, and in the shear, it's -- the torsional
17 moment is reacted by loads in -- in each direction, in
18 flight direction, and this builds up the resultant
19 load, and also some -- some small amount of bending
20 moment and torsional moment are reacted at the main
21 lug.

22 The shear lugs are transferring only tension
23 and compression loads via the link of the lateral yokes
24 which provides the connection between the spherical
25 bearings to the fuselage attachment.

1 MR. MURPHY: And in the analysis that you're
2 doing to date, you're trying -- you're -- you're
3 incorporating all of those loads? You're making sure
4 that you try to account for those in the most accurate
5 manner?

6 MR. WINKLER: Yes.

7 MR. MURPHY: Okay. During the design phase,
8 what other types of failure modes were -- what type of
9 -- what are the types of failure modes that were
10 considered for the lugs themselves? The first one is
11 usually bearing, and then what other failures did you
12 consider?

13 MR. WINKLER: Mainly the tension failure
14 because then you have a separation from -- from -- from
15 the bolt. In the compression scenario, you have
16 certain capability of transmitting compression loads.

17 MR. MURPHY: Okay. Can you -- could you
18 estimate possibly what -- what the repeated load level
19 would have to be to initiate fatigue damage propagation
20 in -- in the fin structure?

21 MR. WINKLER: Concerning a lug?

22 MR. MURPHY: A lug. We'll focus on the lugs,
23 yes.

24 MR. WINKLER: Yeah. You need about 70
25 percent of the failure load for getting fatigue damage,

1 but that is related to -- to a one-step spectrum, not
2 to real -- real-life spectrum. You have to apply 70
3 percent of -- of failure load and then make the cycling
4 with this load. Then you will have onset of fatigue
5 damage maybe when you have cycled up to one million
6 load cycles.

7 MR. MURPHY: Okay. Now, you -- have you done
8 testing on other aircraft to demonstrate that with your
9 lugs?

10 MR. WINKLER: Yes, we do it with all our --

11 MR. MURPHY: Okay.

12 MR. WINKLER: -- designs.

13 MR. CLARK: Let me ask a quick question.
14 When you say it's 70 percent of the failure load, in
15 this case, that 1.9 number we've been hearing about, is
16 that the failure load or -- that's the load that --

17 MR. WINKLER: Yes, it is. 90 tons is the
18 failure load, and if you apply -- if you apply 70
19 percent of this and make a cycling with this load
20 level, we would maybe initiate fatigue damage in the
21 range of one million load cycles.

22 MR. CLARK: Okay. So, you would have -- 70
23 percent of this 1.9 or 2 is about 1.3 or 1.4 --

24 MR. WINKLER: Yes.

25 MR. CLARK: -- load. So, you would have to

1 cycle almost at ultimate with a million times before
2 you're going to start -- you may start fatigue?

3 MR. WINKLER: Exactly.

4 MR. CLARK: Okay.

5 MR. MURPHY: And if it's -- the next question
6 really doesn't matter then because if you're at 70
7 percent of limit, it really doesn't compare to normal
8 operating loads. I'm sorry. 70 percent of the failure
9 load.

10 What were the critical design conditions for
11 the rudder, the rudder structure itself?

12 MR. WINKLER: It is a rudder hinge moment,
13 maximum rudder hinge moment.

14 MR. MURPHY: Could you describe for us the --
15 the two full-scale tests that -- that were performed
16 for the -600 -- well, actually the 310-300?

17 MR. WINKLER: Yes, I can. Initially, we had
18 planned to use only one, one full-scale test, but by
19 accidental damage due to a malfunction of -- of the
20 test, we have to use a second one. The intent was to
21 use one test article for -- to demonstrate the static
22 strength and also the fatigue damage tolerance, and
23 what we actually did is that with the first test
24 article, we demonstrated the static strength and with
25 the second one, we made the fatigue and damage

1 tolerance justification.

2 MR. MURPHY: You may have mentioned it in the
3 opening presentation, but did you put -- you put an
4 enhancement factor on the fatigue loads?

5 MR. WINKLER: Yes, 15 percent.

6 MR. MURPHY: 15 percent. In the beginning of
7 that -- that slide that showed the whole demonstration,
8 you mentioned there were small damages before the
9 initial -- the first fatigue test and then there were
10 large damages for the damage tolerance test.

11 What were the small damages? What were the
12 big damages? What were -- what's the --

13 MR. WINKLER: The small damages are those
14 which -- for which static strength has to be
15 demonstrated which are in general non-visible damages
16 or up to the ability threshold, that were delaminations
17 done by -- by -- either by -- by applying teflon foil
18 or by impact damages up to certain level of energy, and
19 the bigger damages which have been applied for the
20 damage tolerance phase are delaminations up to -- on --
21 on one skin panel side, up to 43 square inches.

22 MR. MURPHY: Okay. And -- and just for
23 clarification, what -- was not the -600R loads used
24 during the static and fatigue testing, it was a lower
25 set of loads -- a higher set of loads?

1 MR. WINKLER: It was the load level for A310-
2 300 was slightly higher than the loads for the -600.

3 MR. MURPHY: Okay. In Exhibit 7GG on Page 9,
4 there's a mention of achieving a goal of 20-percent
5 margin above ultimate, above the 1.5 number. What was
6 the intent or why were -- why were you incorporating
7 that 20 percent above the requirements?

8 MR. WINKLER: That's -- this was used for
9 demonstration, the effect of -- including the effect of
10 -- of non-visible impact damage. So, you have to -- to
11 have a higher static strength to -- to cover these
12 damages.

13 MR. MURPHY: It's almost in a sense -- I
14 guess you could liken it to a special factor almost,
15 like would the forging factors?

16 MR. WINKLER: Well, I -- I would not say that
17 it's a special factor because special factors are for
18 other purposes, but this is necessary. If you -- if we
19 -- if you have to -- to demonstrate non-visible
20 damages, which is linked with -- with the strength
21 degradation, you will have to -- to have a higher
22 initial strength to -- to meet the ultimate load
23 requirement for these damages.

24 MR. MURPHY: Okay. How often were the
25 damages inspected during the fatigue testing and damage

1 tolerance phases?

2 MR. WINKLER: We -- when we applied these
3 very large damages, we have an initial inspection to --
4 to -- to demonstrate the size of the damage. Then we
5 apply -- have applied limit load and after this limit
6 load, we have made an additional measurement. Then
7 there was a measurement, a third measurement at 80,000
8 flights and then after finishing the cycling at a
9 120,000 flights, and during these measurements, no
10 growth was detected for these damages.

11 MR. MURPHY: No growth was detected. What
12 techniques did you use for those?

13 MR. WINKLER: This has been done by -- by
14 ultrasonics.

15 MR. MURPHY: Ultrasonics. Okay.

16 MR. WINKLER: Yes.

17 MR. MURPHY: What other types of subcomponent
18 testing were done during the development phases?

19 MR. WINKLER: We did a lot of tests. I can
20 -- I have -- I have a picture from -- from 1985 which I
21 want to have the whole picture visible. The shaded
22 areas are definitely test articles. We can start at
23 the lower end. We have front spar box built and tested
24 extensively in -- in fatigue with including
25 manufacturing defects and -- and all damage sizes which

1 are required for the damage tolerance justification.
2 We have center lug test with surrounding structure and
3 we have several tests for the rear main lug, and we
4 have an area between Rib 5 and Rib -- Rib 8 where we
5 have tested extensively skin panels with including
6 impact damage up to 6,500 square millimeters. Then the
7 lug area adjacent to the rear spar that was a test
8 including the activators to the rudder and the upper
9 end was additional testing with skin panels with the
10 thinner skin panels which -- which are relevant for
11 this area of the structure.

12 In addition, we performed also a test with
13 ribs and for the rudder where we made several tests for
14 the area where the actuator fittings are attached, the
15 connection between the metal fittings and the skin
16 panels made from -- from -- from honeycomb with -- with
17 tested in fatigue instead of static.

18 MR. MURPHY: For the rudder itself. Did --
19 did the subcomponent tests correlate well with -- with
20 your large-scale tests as far as seeing failures?
21 Basically, initiating the failure where you wanted the
22 failure to initiate in the full-scale test? Okay.

23 MR. WINKLER: Depends on the -- the purpose.
24 Most of the tests were to derive design criteria or
25 failure criteria, and the correlation was the finite

1 element analysis, stiffness and deformation and so on,
2 and concerning the -- the attachment lugs, this
3 correlates very well with the finite element results.

4 MR. MURPHY: Okay. Exhibit 7CC is -- it's
5 entitled "Calculation of the Load Levels Experienced by
6 the Vertical Stabilizer and the Rudder During the
7 Accident". I'm not going to ask you to go through that
8 entire report, but if you could, could you -- could you
9 summarize the results of that report for us?

10 MR. WINKLER: Certainly. Which -- which
11 exhibit?

12 MR. MURPHY: 7CC.

13 MR. WINKLER: Yeah. We analyzed the
14 structure concerning the load level experienced on the
15 -- on all lugs with these three large peaks of the
16 accident flight, and also we investigated the load
17 level experienced by -- by the rudder and the rudder
18 hinge line, and in the summary, you can see that for
19 the first -- for the first peak, which was the name
20 238, the load level at the rear right-hand lug was
21 significantly below limit load requirement. The second
22 case, K316, was at ultimate level, and in the last
23 peak, Y376, we encountered 1.88 times limit load and
24 this exceeds ultimate load requirement by 26 percent.

25 Concerning the rudder, the assessment was

1 done in relation to the static load case demonstrated
2 for certification, and for this case, the hinge moment
3 from Load Case Y376 was only 24.5 percent. The answer
4 from -- from -- is that the damage or the assumption is
5 that the damage at the rudder hinge line and the
6 sandwich structure itself could not be caused by the
7 loads acting on the rudder due to the interface loads
8 between vertical stabilizer and rudder from deformation
9 prior to the accident, and we also assessed the maximum
10 strain level in the skin panels. These exceeded limit
11 load level by a factor of 2.15 at the peak point.

12 MR. MURPHY: Okay. Has -- has the Structures
13 Group identified any pre-existing damage in the -- in
14 the rudder to date? We haven't really addressed that.

15 MR. WINKLER: I -- I have no knowledge about
16 this.

17 MR. MURPHY: Okay. Additionally, your slide
18 in your presentation again showed two other load cases,
19 371 -- B371 and B375. They're not the loads that were
20 used in this analysis. It was -- was the lower load
21 level was used in this analysis?

22 MR. WINKLER: Yes.

23 MR. MURPHY: Okay.

24 MR. WINKLER: So, you can scale up these
25 values with -- with these load results for the two load

1 cases you -- which you just mentioned.

2 MR. MURPHY: Okay. And then, another report,
3 the next report is Exhibit 7DD. It's the "Analysis of
4 the Rupture Sequence of the Vertical Stabilizer During
5 the Accident". Now, understanding that certification
6 only requires you to -- to be good for one failure up
7 to limit load, could you describe or summarize the
8 results, the conclusions in this report for us? 7DD.

9 Actually, Mr. Winkler, it's not necessary for
10 you to summarize what's in that exhibit. It's --

11 MR. WINKLER: What we have done is that we
12 have made the initial calculation and then looked at
13 which point or at which lug we exceed the strength of
14 the -- of this lug, and then we made a failure analysis
15 in removing this connection from our finite element
16 model and this was done until the fittings on -- on the
17 right-hand side have failed completely, and the
18 situation is that we have the first failure on the
19 right rear lugs and we have yoke failure on -- on the
20 shear fittings and subsequently the loads on the center
21 lug is extremely exceeded, exceeded the strength value
22 and this fails next, and we have one -- one picture,
23 264, 264.

24 On -- on -- on this figure, you can see the
25 outcome of this subsequent failure analysis. We have

1 the first failure at the main attachment on the right-
2 hand side. Then we have on the left-hand side
3 transverse fittings. The next failure sends a main
4 fitting right-hand side. The transverse load fitting
5 on the right-hand side, Number 4, sends a main attached
6 fitting right-hand side, Number 5, and then the rest is
7 failure on -- on the -- on the left-hand side.

8 With the sequence as evaluated by comparing
9 the -- with the strength of these lugs or these
10 fittings which are involved in the connection between
11 the fin and the fuselage.

12 MR. MURPHY: You used the load levels then
13 that either came from a subcomponent test or actually
14 the load levels achieved in the full-scale test at the
15 time of failure?

16 MR. WINKLER: Yes. We used -- we used the
17 results from the full-scale test and the load levels
18 which were achieved during the load levels for some
19 other lugs.

20 MR. MURPHY: Okay. Exhibit 7KK attempts to
21 explain a possible scenario for the damage shown to the
22 rudder structure. The only thing I want to find out or
23 note in there is I want to -- are there actuator loads
24 that are expressed in there based on the test results
25 that you performed in Hamburg? Are they achievable

1 during the 587 event or even achievable in service in
2 order to produce --

3 MR. WINKLER: No. No.

4 MR. MURPHY: Okay. And that --

5 MR. WINKLER: Hydraulic pressure is not high
6 enough to achieve these loads, but the -- if the rudder
7 is loaded, then this load is reacted by -- by these
8 actuators and the actuators are capable -- can resist
9 this load because as the hydraulic fluid does not --
10 cannot escape in a -- in a -- in -- during this time.
11 This is locked. The actuators are locked and so the --
12 they can react in this manner which is assumed in this
13 assumption -- in this report.

14 MR. MURPHY: In a dynamic sense of that, --

15 MR. WINKLER: Yeah.

16 MR. MURPHY: -- in an instantaneous moment,
17 the actuators, the fluid --

18 MR. WINKLER: Considered as reaction, not as
19 -- as acting and to provide this moment.

20 MR. MURPHY: Okay. Understanding that your
21 -- your -- your finite element model contained in
22 Exhibit 7BB is -- is work in progress and you're
23 continuing to refine it, can you -- can you explain or
24 just describe what the intended use of that model is
25 for the investigation for -- for us?

1 MR. WINKLER: In terms of the investigation,
2 we -- we have additional test planned with -- with the
3 rear lug to -- to verify the failure loads seen on --
4 on AA-587 and also to replicate these results which we
5 have from the full-scale test, and for this reason, we
6 want to be sure that the test or the test or how the
7 test will be conducted is done in the correct manner.
8 So, we want to -- to provide the correct boundary
9 conditions for this test by -- by making the first
10 analysis and then to -- to be able to -- to apply the
11 moments and -- and forces on these lugs in the correct
12 manner.

13 MR. MURPHY: Okay. You have another Exhibit
14 7EE. You don't have to go to it, but it -- you go
15 through the same analysis for the -- the 903 aircraft.
16 Do you agree with Dr. Ilcewicz's reasons, his
17 explanation for not returning it to service or does
18 Airbus have another point of view on this?

19 MR. WINKLER: It's the same reason. It's
20 already described by Dr. Larry Ilcewicz.

21 MR. MURPHY: Let's just move on to NDI then.
22 How are the manufacturing and in-service allowable
23 damage limits established? Mr. Rackers had indicated
24 that some of this is driven by the Stress Department.

25 MR. WINKLER: Yes. That is done by -- by

1 test. We perform all -- all component tests, include
2 artificial damages, and this -- these damages are then
3 used to -- to define allowable or permitted damages for
4 -- for the production.

5 We actually do the damages for the -- for
6 testing bigger and then go to a lower level which is
7 allowed for -- for -- for production.

8 MR. MURPHY: And the visual inspections then
9 are driven by the no-growth concept and as depicted by
10 Dr. Ilcewicz with the residual strength curves and it's
11 all the same?

12 MR. WINKLER: Yes.

13 MR. MURPHY: Mostly, I'm not going to keep --
14 did you do any -- I'm not even -- given the knowledge
15 of the Airbus composite structures databases, when is
16 the NDI needed for maintenance inspection of composite
17 structures on the 600R vertical fin?

18 MR. WINKLER: NDI has to be applied in
19 maintenance, if we have a visible impact damage or
20 visual damage and for -- for the conditions where we
21 have high loads encountered.

22 MR. MURPHY: Madam Chairman, that -- that's
23 going to conclude my questions. Mostly, it was covered
24 in the presentation and -- and the follow-on
25 presentation -- the previous presentations.

1 So, Dr. Fox?

2 DR. FOX: Thank you, Mr. Murphy.

3 As Mr. Murphy indicated earlier, I have a few
4 questions regarding fracture features in -- in tested
5 lugs. I'd like to discuss the detail tests first. I
6 guess, first looking at the rear lug that was tested in
7 tension, could you describe the visual appearance of
8 that fracture, where the fracture was located?

9 MR. WINKLER: For the component test?

10 DR. FOX: For -- for the -- yeah. The
11 detail.

12 MR. WINKLER: I have a photograph. You can
13 see how it fails. I think there, it says similarity to
14 -- to the AA-5 -- 587 lug failure.

15 DR. FOX: Could you indicate which direction
16 is the forward direction in that?

17 MR. WINKLER: You see there the load
18 resultance is in this direction, and we have three
19 failure -- failure areas. This failure is nearly
20 equivalent to the 587 and also this -- and this is a
21 failure which is caused by -- by the rupture mode by --
22 by pulling out these -- these are pushed out.

23 DR. FOX: So, -- so, essentially, what you're
24 saying is that on the aft side or on the right side of
25 the picture, that -- that is a secondary fracture as a

1 result of the test?

2 MR. WINKLER: Yes, sir. Yes.

3 MEMBER BLACK: Could we have some forward,
4 aft, left, right direction on that photograph? Which
5 way is forward?

6 MR. MURPHY: Forward to the left. Would
7 forward be to the left and essentially maybe slightly
8 up?

9 MR. WINKLER: Forward is to the left.

10 MR. MURPHY: Forward is to the left, aft is
11 to the right, and where he had his pen the first time
12 was the resultant load vector.

13 DR. FOX: Okay. Let's see. I guess in -- in
14 the rear lug tested in compression, what was -- what
15 was the failure mode? Where -- where was the failure
16 located in -- in that case?

17 MR. WINKLER: It was in compression, the
18 forward lug failed above rip one in the --
19 unfortunately, I've no figure for this, but the
20 fracture is visible on -- on the inside and outside
21 surface by -- by compression failure.

22 DR. FOX: Okay. And that's still within the
23 -- the transition region between where -- where you
24 still have the -- the pre-cured halves transitioning
25 into the --

1 MR. WINKLER: Yes. The fracture happens
2 inside. The inner lug half is larger than the outer
3 one, and the fracture is -- is in -- in the inner lug.

4 DR. FOX: Okay. And above --

5 MR. WINKLER: It's not --

6 DR. FOX: Above the --

7 MR. WINKLER: -- directly supported, but it's
8 in -- in --

9 DR. FOX: Near the border?

10 MR. WINKLER: In the -- no. It's more close
11 to rip one.

12 DR. FOX: Okay. Was -- is -- is the -- the
13 compression fracture, was it oriented approximately
14 perpendicular to the fiber direction or -- or what was
15 the approximate orientation of -- of the compression
16 fracture?

17 MR. WINKLER: It's like in the elliptic shape
18 of -- of fracture.

19 DR. FOX: Okay. I guess next, going to the
20 detailed test on the center lug in -- in tension, what
21 did the fracture appearance -- where was the location
22 of that fracture?

23 MR. WINKLER: It was also above rip one.

24 DR. FOX: Okay. Similar elliptical shape?

25 MR. WINKLER: Yes, yes.

1 DR. FOX: Okay. Did -- did it have an
2 appearance similar to the right center lug in the
3 accident?

4 MR. WINKLER: Yes. It's nearly the same line
5 of fracture visible on -- on the part.

6 DR. FOX: Okay. And it's my understanding in
7 compression, there was no center lug tested to failure
8 in compression, is -- or was -- was -- what --

9 MR. WINKLER: No.

10 DR. FOX: No. Okay. And then, looking at
11 the -- the front detail tests, the front lug, what was
12 the location of the fracture for that lug in tension?

13 MR. WINKLER: In tension, it's in that
14 section failure, and in compression, the same. It's
15 above rip one failure, compression failure, and the
16 delaminator of rip one.

17 DR. FOX: Okay.

18 MR. WINKLER: We have never bearing failure
19 for -- for those types of lugs.

20 DR. FOX: Okay. No bearing failures. Okay.
21 And then, the location on the front lug in
22 compression, was it a similar elliptical shape? The
23 location of the fracture?

24 MR. WINKLER: Yeah. It's -- okay. It's --
25 you can -- you can say it's like an elliptical, but it

1 sets on the front spar and then it goes down to
2 probably to one stringer to rip one.

3 DR. FOX: Okay. Okay. Then moving to the
4 full-scale test, what lugs failed or lug or lugs failed
5 in that test?

6 MR. WINKLER: On the full-scale test, only
7 the right-hand side lug, rear right-hand side lug
8 failed.

9 DR. FOX: And that -- that lug was in
10 tension?

11 MR. WINKLER: It was in tension.

12 DR. FOX: Okay. And we have a picture. And
13 do you have a picture of that failure?

14 MR. WINKLER: No, unfortunately, not.

15 DR. FOX: Okay. And what -- what was the
16 failure appearance and location of that fracture?

17 MR. WINKLER: It looks very similar to -- to
18 the detail test, to the component test.

19 DR. FOX: Okay. That's all the questions
20 that I have. Thank you.

21 ACTING CHAIRMAN CARMODY: Yes. FAA, any
22 questions of the witness? Oh, I'm sorry. Mr. Benzon,
23 I missed you. One more question on the Technical
24 Panel. Please go ahead.

25 MR. BENZON: Yes, ma'am. Thank you.

1 Herr Winkler, I'm interested in the bolts
2 that attach the fin to the fuselage. They're obviously
3 installed, tightened and then cotterpinned. If they
4 rotate or are found rotated upon a maintenance
5 inspection perhaps, what does this mean?

6 MR. WINKLER: It has no -- no -- no impact on
7 -- on -- on -- on safety.

8 MR. BENZON: Thank you.

9 ACTING CHAIRMAN CARMODY: Dr. Kushner?

10 DR. KUSHNER: Yes. When you did the detail
11 tests that you were talking about in response to Dr.
12 Fox, was the load -- failure loads and tension higher
13 than in compression or the other way around?

14 MR. WINKLER: The rear lug was tested by two
15 specimens, one in tension and one in compression after
16 rupture, and both failure loads were very close. One
17 was a 103 tons and the other was -- was about 101 tons.
18 So, the strength is similar but the failure mode is, of
19 course, different.

20 DR. KUSHNER: Okay. Well, in your reports,
21 you reported a tension failure of about a 150, 1-0-5-0,
22 and 1-0-0-3 for compression. Is that incorrect?

23 MR. WINKLER: No. I cannot remember such a
24 value.

25 DR. KUSHNER: Okay. Dr. Ilcewicz mentioned

1 that typically composites fail in compression at lower
2 stress levels than in tension and yet on these
3 components, we're seeing tension failures. Is there
4 something associated with the nature of the way you
5 designed that causes that?

6 MR. WINKLER: Oh, I think the -- the
7 statement, what was done by Dr. Ilcewicz is concerned
8 to the plain laminate, not -- not to the lug structure
9 where we have much more complicated geometry. We have
10 glide drops and so on. We have transitioned to -- to
11 -- to the skin with -- with stringers and so on.

12 DR. FOX: Okay. Going back, how did you
13 validate the accuracy of your finite element
14 calculations during the design and certification phase?

15 MR. WINKLER: You mean the analysis for the
16 complete fin?

17 DR. KUSHNER: Yes.

18 MR. WINKLER: Yeah. We have applied an
19 amount of strain gauges on our vertical stabilizer, if
20 we scale test, and also performed deflection
21 measurements and this has been correlated to the finite
22 element results, and they were in accordance.

23 DR. KUSHNER: Okay. And did you have strain
24 gauges on the attachment lugs during those tests that
25 you compared with the finite element calculations?

1 MR. WINKLER: Directly around the bushing, I
2 don't -- I don't think so. There were no --

3 DR. KUSHNER: Okay.

4 MR. WINKLER: But above rip one where we have
5 access to -- to -- to -- to -- we -- we have some.

6 DR. KUSHNER: Okay. But the lug loads that
7 you determined for failure in your full-scale test come
8 from the finite element calculations, is that correct?

9 MR. WINKLER: No. They are measured.

10 DR. KUSHNER: They are measured?

11 MR. WINKLER: Measured, yes.

12 DR. KUSHNER: And --

13 MR. WINKLER: We have the -- I can't picture
14 how the full-scale test has been performed. The
15 reaction forces which simulates the fuselage are
16 provided by -- also by hydraulic cylinders and all
17 loads which are introduced to the structure are
18 measured by load cells. So, we know exactly -- we know
19 exactly which load is introduced to -- to -- to the
20 lugs.

21 DR. KUSHNER: Well, --

22 MR. WINKLER: There is a picture of the fin.
23 It's lying on the -- on the rear spar and the big beams
24 which are three beams that are the supporting structure
25 representing the fuselage. We have two -- two fixed

1 points on the one by -- by what's -- what -- by -- by
2 two rods. Also including load cells and all other
3 direction activity by -- by hydraulic cylinders which
4 -- which are in close tolerance with the requirements
5 from -- from our finite element calculation, and so the
6 -- the rupture load is directly linked to -- to the
7 load introduction of these cylinders and by the
8 geometry of these beams on which the fin box is mounted
9 during the test.

10 DR. KUSHNER: Thank you.

11 ACTING CHAIRMAN CARMODY: Mr. Clark?

12 MR. CLARK: Just a quick follow-up. Mr.
13 Benzon asked about a rotated pin and you commented that
14 it wasn't significant in the strength of the -- why
15 not? Why is it not critical?

16 MR. WINKLER: It has no influence on load
17 transfer. The operation is -- is safe, and the
18 movements it makes are only very small rotations due to
19 the flexibility of the aircraft, and we have also seen
20 these movements during full-scale testing, and there's
21 only maybe a concern of wear. That is all.

22 MR. CLARK: Okay. In the -- if the -- my
23 understanding, it's a comb-type bolt that wedges in, --

24 MR. WINKLER: Yeah.

25 MR. CLARK: -- and if that's loose enough

1 that we get the slight rotation, I guess, the -- the --
2 what it would appear then -- let me ask it this way.
3 Is -- I guess the torque of that, it may not be
4 critical at all then in the overall strength for a
5 short period of time.

6 MR. WINKLER: Please repeat your question.

7 MR. CLARK: Okay. My understanding is, is
8 that, the -- the comb bolt is torqued, the comb and the
9 bolt, to a proper level, and will that bolt rotate if
10 the torque is proper?

11 MR. WINKLER: Yes.

12 MR. CLARK: Okay. Thank you.

13 MR. WINKLER: It depends on -- on -- on the
14 load level which is applied on the fin. I think on low
15 load levels, nothing happens, and if there is some
16 peaks in there, maybe a slight rotation.

17 MR. CLARK: Okay. So, what I'm after is the
18 -- I guess that I understand, is that I don't have to
19 loosen the bolt then to get rotation in normal service?
20 I can get normal -- I can get rotation with a
21 properly-torqued bolt?

22 MR. WINKLER: Yes.

23 MR. CLARK: Okay.

24 ACTING CHAIRMAN CARMODY: All right. Moving
25 to the parties, FAA, Mr. Donner?

1 MR. DONNER: Yes, I do have one question, and
2 it's a multiple choice question.

3 So, the aft right lug failure on the accident
4 aircraft. Would you say that that aft right lug failed
5 due to (1) a shear-out mode, (2) a net section stress
6 concentration, or (3) a combination of the two under
7 the accident loading?

8 MR. WINKLER: It's not a net section failure.
9 It's -- I think it's a shear-out.

10 MR. DONNER: Okay. Thank you very much.

11 ACTING CHAIRMAN CARMODY: Thank you.

12 American, Mr. Ahearn, any questions?

13 MR. AHEARN: Yes, Madam Chairman. Thank you.

14 Gentlemen, it's still afternoon, so good
15 afternoon. Just a few topics I'd like to touch upon.

16 Exhibit 7AA refers that Airbus determined
17 lateral gusts to be the critical loading condition for
18 the rear lug. Were the loading conditions to which
19 Airbus designed the composite vertical stabilizer any
20 different than the loading condition for the metal tail
21 from B2B4?

22 MR. WINKLER: The metal tail has exactly the
23 same design conditions, also the lateral gust.

24 MR. AHEARN: So, then, the -- I presume that
25 the rear lug on the metal tail would also be the

1 critical component?

2 MR. WINKLER: No.

3 MR. AHEARN: What --

4 THE WITNESS: The load is different on metal
5 structure.

6 MR. AHEARN: What -- do you know what the
7 critical components were on the metal tail?

8 MR. WINKLER: Yes. The compression failure
9 of the skin panel.

10 MR. AHEARN: So, with that, would it have
11 broken higher than the lug? High above -- higher above
12 the fuselage --

13 MR. WINKLER: No, not very high. The maximum
14 load level is just above the lug, and there, the
15 margins are low in compression. We have buckling and
16 then the margins are very low.

17 MR. AHEARN: Do you know if there would be
18 enough left to have any control of the aircraft?

19 MR. WINKLER: I do not know how many fin box
20 is necessary for -- for control of the aircraft. I
21 don't think that -- it may be one meter above the
22 attachment will -- that would be the failure.

23 MR. AHEARN: Okay. Let me just move on to a
24 different question similar to this damage. Given the
25 restraints of the existing fuselage structure, we

1 talked a little bit about that, could the aft lug have
2 been designed for a higher load capacity, and again,
3 with the expectation that this lug, the rear lug, would
4 fail first?

5 MR. WINKLER: I consider that the load level
6 we have fatigued is enough concerning to the -- related
7 to the requirements, and so there is no necessary to --
8 to have a higher strain lug.

9 MR. AHEARN: So, it meets -- in other words,
10 it meets the FARs?

11 MR. WINKLER: Yes, of course, and exceeds the
12 FARs. Requirement is 1.5 times limit load and we have
13 reached 1.9 times limit load.

14 MR. AHEARN: If -- do you know if you have
15 the attachment lugs made of metal instead of composite,
16 would the lugs have failed differently?

17 MR. WINKLER: That is speculation. I cannot
18 answer to this question.

19 MR. AHEARN: Okay, okay. I'm just seeing if
20 you have any knowledge of it.

21 Mr. Winkler, you're familiar with the term
22 "balanced joint", are you not?

23 MR. WINKLER: With what, please?

24 MR. AHEARN: The term "balanced joint" or
25 "balanced connection"? What I'm referring to is where

1 the composite lug joins with the clevis pin to the
2 empennage or -- or to the tail structure.

3 MR. WINKLER: I'm --

4 MR. AHEARN: Let me bring up a picture.
5 Maybe I can help you with it. Could you bring up
6 Exhibit 7B as in Baker, Pages 33 and 34?

7 ACTING CHAIRMAN CARMODY: Is that 7B as in
8 Baker?

9 MR. AHEARN: 7B as in Bravo.

10 ACTING CHAIRMAN CARMODY: Yeah. That's not
11 an exhibit that this witness was responsible for.

12 MR. AHEARN: I just want to use it as an
13 illustration, ma'am.

14 ACTING CHAIRMAN CARMODY: Does the witness
15 object? Have we brought it up? I don't see it on here
16 yet.

17 MR. WINKLER: Picture from the -- from the
18 wreckage?

19 MR. AHEARN: Yes, sir.

20 MR. WINKLER: Okay.

21 MR. AHEARN: It is? Okay. If you can see
22 it, I just want to take a quick peak at it. Maybe it
23 will help what I'm trying to describe as a balanced
24 joint to you.

25 ACTING CHAIRMAN CARMODY: What page of the

1 exhibit?

2 MR. AHEARN: Page 33 and 34. That's one. If
3 you could, 51, and then if you could bring up Page 34,
4 I believe it's Figure 54 -- well, 54 on the bottom.
5 The next figure, please. That's it.

6 If you look at these pictures, sir, it
7 appears that the loads were not distributed between all
8 of the objects that were joined. It appears that the
9 failure was strictly at the lug, and let me see if I
10 can give you kind of a human illustration of what I
11 mean from a balanced joint standpoint.

12 If I have three 18-year olds of equal size
13 pulling on each other, they're probably going to stay
14 pretty stable, but if I have a five-year old pulling on
15 one arm and an 18-year old pulling on my other arm, I'm
16 going to be off balance. So, that's what I'm trying to
17 refer to as a balanced joint.

18 ACTING CHAIRMAN CARMODY: Mr. Winkler, if
19 this is -- is this a question you can answer? Because
20 I find it a little confusing.

21 MR. AHEARN: Well, let me ask the question
22 and see if you can answer it.

23 ACTING CHAIRMAN CARMODY: Try and clarify
24 because this is not an exhibit the witness has.

25 MR. WINKLER: You mean the comparing the

1 center lug with the rear lug?

2 MR. AHEARN: No. What I'm trying to say in
3 the one joint, what were the relative strengths of the
4 composite tail lug, the metal fuselage clevis and the
5 connecting pin? Were they balanced?

6 MR. WINKLER: The metal fuselage lug is --
7 has a different design condition. It is made for
8 fatigue damage. So, --

9 MR. AHEARN: So, it's stronger?

10 MR. WINKLER: Yes. It has to -- to -- to
11 test to -- to fatigue requirements and so that is a
12 different design condition.

13 MR. AHEARN: Right. And -- and
14 unfortunately, we don't have another picture here, but
15 it appears that none of the clevises on the fuselage
16 yielded at all, --

17 MR. WINKLER: Hm-hmm. That's correct.

18 MR. AHEARN: -- and -- and -- and yet the
19 lugs, all the lugs yielded, and what I'm looking to see
20 is if you have a knowledge of the distribution of
21 -- of the loads on the -- the joint itself from the
22 tail to the fuselage or from the fuselage to the tail
23 because it appears that all the loads were on the tail
24 and that there wasn't anything on the -- the joint on
25 the fuselage.

1 MR. WINKLER: The metal lugs are designed by
2 -- by fatigue conditions, and so they are -- if there
3 is no fatigue damage, they have to be stronger, of
4 course.

5 MR. AHEARN: Okay. Thank you.

6 Let's move on to another subject. It's my
7 understanding that you did work on the transition from
8 the B2B4 to the 310 composite tail, is that correct?

9 MR. WINKLER: No.

10 MR. AHEARN: No? Do you have any knowledge
11 of the strength or the robustness of those tails?

12 MR. WINKLER: The metallic one.

13 MR. AHEARN: Yes. Do you know if --

14 MR. WINKLER: I know -- I know the reserve
15 factors, yes.

16 MR. AHEARN: Do you know if one's more robust
17 than the other?

18 MR. WINKLER: I think they have equal level.

19 MR. AHEARN: Okay. Thank you.

20 Just a couple more topics for you, sir. We
21 have heard testimony about changes in design of the
22 lugs in subsequent models following the 600, airplanes
23 that followed in -- in development from the 600. As a
24 result, do you still expect the aft lug to rupture
25 first in full-scale testing on the other models?

1 MR. WINKLER: Which other models do you mean?

2 MR. AHEARN: The 310, the -- I'm sorry, not
3 the 310. The 320, the 330, the 340? Is the aft rear
4 lug still the lug that will rupture on the -- on -- on
5 the models that came after the 300?

6 MR. WINKLER: The -- for the 320 and 340, the
7 same lugs are -- have -- are the highest loaded and so
8 they are -- would be failed for us, yes.

9 MR. AHEARN: And the 330?

10 THE WITNESS: We have two Model 330-200 and
11 300. So, the 300 is -- has the same design principle
12 as the -- from the principle as the 340-300 and so it
13 applies the same statement what I made, and the 330-200
14 has failed in a different mode.

15 MR. AHEARN: And -- and --

16 MR. WINKLER: Because it is -- historically,
17 it is because we -- when we designed this fin box, we
18 have the A340-600 in mind, and we have made the -- the
19 attachments to -- to cover the load levels for the 340-
20 600 so they are stronger.

21 MR. AHEARN: Okay. And -- and again just to
22 clarify, you would expect that to happen in your full-
23 scale testing? That's what you saw in your full-scale
24 -- in your full-scale testing?

25 MR. WINKLER: For -- for -- for the -- for

1 the 320, 340, basic -- the basic 340, we have made such
2 tests and it is the same -- the same failure mode.

3 MR. AHEARN: Okay. Now, just one final
4 topic. You had highlighted in your presentation that
5 the airplane had been certified in the United States
6 and Europe. Has the 300 ever been declined
7 certification in any country?

8 MR. WINKLER: I'm not familiar with this.

9 MR. AHEARN: Okay. Thank you, sir.
10 Madam Chairman, that's all my questions.

11 ACTING CHAIRMAN CARMODY: Thank you.

12 Allied Pilots, Captain Pitts?

13 CAPT. PITTS: Thank you, ma'am.

14 Good afternoon, sir.

15 MR. WINKLER: Good afternoon.

16 CAPT. PITTS: For certification purposes, did
17 Airbus consider any rudder maneuver cases not directly
18 required by FAR.351 for structural substantiation of
19 the A300-600?

20 MR. WINKLER: That's not my expertise to
21 answer to this question. Sorry.

22 CAPT. PITTS: I'm sorry. I thought -- I
23 thought I saw certification of the -- of the structure
24 in there. Would you have been consulted on that?

25 MR. WINKLER: On what?

1 CAPT. PITTS: On meeting certification
2 criteria in terms of the structure?

3 MR. WINKLER: Yes, of course.

4 CAPT. PITTS: And such --

5 MR. WINKLER: But for -- for the
6 requirements, which are written down in FAR-25, and for
7 these maneuvers, we cover all requirements.

8 CAPT. PITTS: Are you -- are you aware of
9 anything beyond those requirements that were -- were
10 considered in the design?

11 MR. WINKLER: No.

12 CAPT. PITTS: Okay, sir. Any new designs?
13 Do the -- you mentioned the new design.

14 MR. WINKLER: All -- all our aircraft comply
15 to -- to the latest requirements from JAR or FAR.

16 CAPT. PITTS: All right, sir. And -- and
17 consider no further requirements, other than those
18 specified in the regulations? In other words, it
19 wouldn't take a look at additional rudder movements,
20 maybe a rapid rudder from neutral and over-swing, maybe
21 a full reversal?

22 MR. WINKLER: That may be. There may be
23 studies by -- by the Loads Departments or by the Flight
24 -- Flight Departments, but I am a stress man and I use
25 the load input which I get for certification from the

1 Loads Department. So, I'm not familiar --

2 CAPT. PITTS: All right.

3 MR. WINKLER: -- with studies which are made
4 somewhere else.

5 CAPT. PITTS: All right, sir. Very well.
6 You mentioned in your presentation, I think, and
7 others, we've heard the same thing, that the aft lugs
8 failed first, is that correct?

9 MR. WINKLER: During the accident.

10 CAPT. PITTS: In the --

11 MR. WINKLER: In my opinion, yes.

12 CAPT. PITTS: Yes, sir. Are the -- the aft
13 lugs designed to the same criteria as the others? Are
14 they -- or are they weaker?

15 MR. WINKLER: The aft lug is designed for the
16 failure condition when center lug fails. It's the same
17 scenario which we have described in the beginning of my
18 -- my witnessing and -- but this -- for the rear lug,
19 the condition, the failure condition is nearly equal to
20 the normal condition when all lugs are intact. So, we
21 comply with ultimate load, load requirement for the
22 rear lug and we comply with the fail-safe condition at
23 the rear lug when -- when the center lug fails.

24 For the other lugs, the situation is -- is
25 different. The center lug has to be much stronger to

1 cover the failure scenario on the rear lug. So, that
2 is why it's stronger and the strength is -- is -- is
3 higher than necessary for -- for the normal condition
4 when all lugs are intact.

5 CAPT. PITTS: Now, did I understand the
6 presentation correct that as the loads build up on the
7 structure, they tend to shift in favor of the aft
8 structure, the aft lugs?

9 MR. WINKLER: No.

10 CAPT. PITTS: That's not correct?

11 MR. WINKLER: That's the wrong
12 interpretation. Yeah.

13 CAPT. PITTS: All right. Okay. From a
14 systems safety design perspective, wouldn't it be
15 better for the vertical stabilizer to have some of its
16 most critical components some place other than at the
17 lugs?

18 MR. WINKLER: Please, once more.

19 CAPT. PITTS: Yes, sir. From a systems
20 safety design perspective, --

21 MR. WINKLER: Systems?

22 CAPT. PITTS: Systems safety.

23 MR. WINKLER: I'm -- I'm not responsible for
24 structure, not for system.

25 CAPT. PITTS: All right, sir. From a -- from

1 a design safety perspective of the structure, wouldn't
2 it be far better for the vertical stabilizer to have
3 its most critical component some place other than at
4 the lugs?

5 MR. WINKLER: I do not understand your
6 question.

7 CAPT. PITTS: All right, sir. I'll see if I
8 can rephrase it.

9 MR. WINKLER: Hm-hmm.

10 CAPT. PITTS: The most critical component in
11 the structure is where it attaches, is that correct?
12 Not further up --

13 MR. WINKLER: Yes.

14 CAPT. PITTS: -- in -- into the -- into the
15 --

16 MR. WINKLER: Concerning -- concerning the
17 gust load condition or the load condition, which we
18 have had in the accident.

19 CAPT. PITTS: All right, sir. And -- and is
20 that -- is that same philosophy in other vertical
21 stabilizers that have been designed by Airbus?

22 MR. WINKLER: That is no philosophy. We --
23 we -- in -- in our opinion, the load level of the
24 strength or the strength level which we have built in
25 this pin significantly exceeds the requirements and so

1 there is no concern about this.

2 CAPT. PITTS: All right. I referenced the
3 critical point on the vertical stabilizer. So,
4 subsequent aircraft models and designs of vertical
5 stabilizers have this same sort of design concept?

6 MR. WINKLER: That is not a design concept.

7 CAPT. PITTS: All right. Very well. I'll
8 move on to another area.

9 Did you participate in the investigation of
10 the Flight 903 event that took place in May of 1997?

11 MR. WINKLER: I was not aware in '97, but of
12 course, I -- I'm aware since the investigation of -- of
13 the load exceedances.

14 CAPT. PITTS: So, you did not participate in
15 the investigation or any of the loads analysis or
16 structures reviews?

17 MR. WINKLER: No, no.

18 CAPT. PITTS: All right, sir. Would that
19 also be the same case for the investigation of the
20 previously-referenced Interflug flight?

21 MR. WINKLER: Yes, it is the same.

22 CAPT. PITTS: Since you didn't participate in
23 the investigation, can you tell me when you or when the
24 company, Airbus, became first aware of the -- of the
25 fact that the vertical tail on Flight 903 exceeded

1 ultimate load?

2 MR. WINKLER: I think that has been answered
3 several times during this hearing. This question has
4 been answered several times during the hearing.

5 CAPT. PITTS: Can you refresh my memory? I
6 don't know the answer to it.

7 MR. WINKLER: In '97, the -- with an
8 assessment which reveals that ultimate load has
9 probably been achieved or encountered by this aircraft.

10 CAPT. PITTS: All right. So, the answer is
11 1997?

12 MR. WINKLER: Yes, the answer is 1997.

13 CAPT. PITTS: All right. And when did you
14 notify either the National Transportation Safety Board
15 or the operators of the aircraft that the -- the
16 ultimate load had been exceeded?

17 MR. WINKLER: That's not in my responsibility
18 to make notifications to NTSB.

19 CAPT. PITTS: All right, sir. Did -- did the
20 fact that it was in fact exceeded, that it -- that it
21 did in fact exceed the ultimate limit, is that in your
22 area of concern as far as your responsibilities within
23 the company and reviewing the system and its
24 robustness?

25 MR. WINKLER: The structure, only the

1 structure.

2 CAPT. PITTS: And you reviewed that -- that
3 --

4 MR. WINKLER: Yes.

5 CAPT. PITTS: Those -- those values and --
6 and --

7 MR. WINKLER: In 2000 -- this year.

8 CAPT. PITTS: All right, sir. Were there any
9 analytical tools or methods not available to Airbus in
10 1997 to ascertain the overloads that are available
11 today and that were used by Airbus in support of the
12 calculations for the review on the data of 903?

13 MR. WINKLER: I think this question has been
14 answered by Mr. Curbillon this morning.

15 ACTING CHAIRMAN CARMODY: Yes. Captain
16 Pitts, let's try and get some new information here. If
17 -- if you have more questions, let's proceed with them.
18 I think we've asked this witness several times and
19 let's move on.

20 CAPT. PITTS: Okay. I'm curious if there's
21 been any refinement in the methods that are used to do
22 -- do the structures analysis since the 1997 event.
23 Has there -- has there been a modification in the -- in
24 the methodology or a refinement?

25 MR. WINKLER: No.

1 CAPT. PITTS: Okay.

2 MR. WINKLER: Concerning structure
3 evaluation, no, nothing. Concerning other domains, I
4 cannot speak.

5 CAPT. PITTS: All right, sir. In terms of
6 the -- the damage that the 903 tail suffered, you -- I
7 think it was stated that after the accident, the 587
8 accident, that it was within Airbus acceptable limits,
9 and then later on, the recommendation was that it
10 should be replaced as it had exceeded ultimate limit.

11 Can you -- can you give me the -- the change
12 in heart there? Can you help me understand why, once
13 it was known that the load limit, plus its safety
14 factor, had been exceeded, that there was now a
15 recommendation to in fact go forward after the previous
16 recommendation had been to not do so?

17 MR. WINKLER: I'm -- I'm only aware with the
18 decision from Airbus that the fin is no longer
19 serviceable.

20 CAPT. PITTS: All right, sir. In reviewing
21 the structure, if you were informed today that a
22 structure had exceeded ultimate limit, would it be your
23 recommendation to replace it?

24 MR. WINKLER: From the situation that the
25 load level is unknown, we have heard in the morning

1 that there is some deficiencies concerning the DFDR
2 recordings, I would say yes, that it should be removed.

3 CAPT. PITTS: And I wasn't real specifically
4 speaking to 903. So, I apologize. I -- it was a
5 hypothetical in terms of your assessment of a structure
6 that was reported to have exceeded ultimate limit load.
7 Would you recommend that it be replaced?

8 MR. WINKLER: Once more, please.

9 CAPT. PITTS: A structure. This is a
10 hypothetical situation. You were made aware that a
11 structure had exceeded its ultimate limit load. Would
12 it be your recommendation that it be replaced?

13 MR. WINKLER: Depends on the load case.
14 There are some load cases not critical for -- for --
15 for -- for the lugs. It depends on the type of load
16 case and we have to decide case-by-case when -- when we
17 make -- have to make the decision to remove it from
18 service or not.

19 CAPT. PITTS: All right, sir. Just very
20 quickly, my last area, couple of questions. We've
21 learned that this aircraft, the accident aircraft, 053,
22 was involved in testing prior to delivery. Are you
23 familiar with the type of testing that is underwent?

24 MR. WINKLER: No, I am not aware of this.

25 CAPT. PITTS: All right, sir. Reference the

1 repair, as a matter of fact, we saw a picture of the
2 lug just a moment ago. In terms of a repair method,
3 did -- did that repair methodology equal or exceed the
4 -- the design criteria of the -- of the laminate
5 structure?

6 MR. WINKLER: The repair which has been done
7 fully restores the strength capability of this lug.

8 CAPT. PITTS: All right, sir. How -- do you
9 know how that lug was -- was either in the
10 manufacturing or in the testing process damaged?

11 MR. WINKLER: From 587?

12 CAPT. PITTS: From the accident aircraft.

13 MR. WINKLER: No, no.

14 CAPT. PITTS: Yes, sir.

15 MR. WINKLER: There were indications which
16 was -- the result of which was done in the inspection.

17 CAPT. PITTS: Very well. Thank you, sir.

18 I have no further questions.

19 ACTING CHAIRMAN CARMODY: Airbus, Dr. Lauber?

20 DR. LAUBER: Thank you, Madam Chairman.

21 Just one or two questions here. Mr. Winkler,
22 you've been asked a number of questions regarding the
23 -- the high fin load cases that were looked into
24 subsequent to the 587 accident.

25 Isn't it true in many of those, at least

1 those that involve loss of control, that the -- the
2 excessive loads experienced by the airframe weren't
3 limited simply to the vertical fin? Weren't other
4 structures also subjected to excessive loads?

5 MR. WINKLER: Yes, it's correct.

6 DR. LAUBER: Okay. Thank you.

7 You've been asked a number of questions about
8 if you designed a certain component to be stronger,
9 wouldn't that be -- wouldn't that result in a better
10 design or something? If you designed the rear fin lug
11 to be stronger than it is, wouldn't that simply mean
12 that some other lug would fail first or some other
13 component in the vertical stabilizer would fail first?

14 MR. WINKLER: Yes. If the failure is
15 anywhere, can happen anywhere, concerning to the -- to
16 the strength level.

17 DR. LAUBER: When a structure breaks,
18 something breaks first in it?

19 MR. WINKLER: Yes, something breaks first.

20 DR. LAUBER: Thank you. I have no further
21 questions. Thank you.

22 ACTING CHAIRMAN CARMODY: Thank you.

23 Moving to the Board, Member Goglia?

24 MEMBER GOGLIA: No questions.

25 ACTING CHAIRMAN CARMODY: Member Black?

1 MEMBER BLACK: No questions.

2 ACTING CHAIRMAN CARMODY: Are there any
3 further questions from the Technical Panel? Dr.
4 Kushner?

5 DR. KUSHNER: Erhard, we had some questioning
6 that seemed to imply that it would be a better design
7 if everything failed together at the same time. Within
8 the design community, is that considered a good
9 philosophy?

10 MR. WINKLER: I think that is a dream but not
11 -- not realistic.

12 DR. KUSHNER: Okay. I mean, typically, one
13 worries if you have to be concerned with the entire
14 structure failing at the same time. It's not
15 considered an optimum design.

16 Also, there seemed to be questions implying
17 that in a structure like this, where all the load has
18 to eventually get down to the attachment points, the
19 lugs, there's no other place for it to go, that it
20 would be a better design if the first failure was some
21 place else. Does that mean anything? Does it really
22 change the overall ability of the structure to transfer
23 the loads to the airplane?

24 MR. WINKLER: Please, once more.

25 DR. KUSHNER: Okay.

1 MR. WINKLER: I didn't catch it fully.

2 DR. KUSHNER: The point is, the vertical fin
3 is taking load that has to -- is needed to maneuver the
4 aircraft.

5 MR. WINKLER: Yes.

6 DR. KUSHNER: Having it fail some place else
7 first doesn't really help in terms of the functionality
8 and the requirement to get that load down into the
9 airplane. So, you don't gain anything.

10 MR. WINKLER: No. That's correct.

11 DR. KUSHNER: Okay. Thank you.

12 ACTING CHAIRMAN CARMODY: Was that it, Dr.
13 Kushner. Okay.

14 Is there any additional questions from any of
15 the parties? I see heads shaking.

16 Well, my thanks, Dr. Winkler, for your
17 testimony. We appreciate your time and your -- your
18 testimony.

19 (Whereupon, the witness was excused.)

20 ACTING CHAIRMAN CARMODY: And let's move
21 quickly to the first of the NASA witnesses. I'd like
22 to do one more today, if we can. Thank you.

23 MS. WARD: I'd like to call Dr. William
24 Winfree. Please raise your right hand.
25 Whereupon,

1 DR. WILLIAM (BILL) WINFREE
2 having been first duly sworn, was called as a witness
3 herein and was examined and testified as follows:

4 MS. WARD: Thank you. Please have a seat.

5 Dr. Winfree, could you please state your full
6 name, your current employer, and your business address?

7 DR. WINFREE: My full name is William Paul
8 Winfree.

9 MS. WARD: Mike, please.

10 DR. WINFREE: It's on now. Okay. My full
11 name is William Paul Winfree. My current employer is
12 NASA Langley in Hampton, Virginia, and I'm a research
13 physicist with them.

14 MS. WARD: And how long have you been a
15 research physicist for them?

16 DR. WINFREE: About 24 years.

17 MS. WARD: And what are your duties and
18 responsibilities in your current position, and please
19 list any training or education that you received to
20 qualify you for your position?

21 DR. WINFREE: Okay. Well, first of all, my
22 education was a Bachelor's of Science in Physics, a
23 Master's of Science in Physics, and a Ph.D. in Physics.
24 Since I've been at NASA Langley, I've been doing NDE
25 research for almost 24 years and that's been looking at

1 composites as well as metal structures. Typically,
2 what we do is we develop new techniques for inspection
3 of either aerospace or aircraft structures.

4 In the last 10 years, we've been working on
5 things like Aging Aircraft Program. Actually, NASA
6 equivalent of the Aging Aircraft Program which is an
7 Airframes Structural Integrity Program which is looking
8 at developing techniques, NDE techniques for aircraft
9 and then we've also had the High-Speed Civil Transport
10 Program which was looking at primary, looking at
11 composites for high-speed aircraft and also the
12 Advanced Composites Technology Program which was
13 looking for trying to insert large composite primary
14 structure in the aircraft.

15 MS. WARD: Okay. Dr. Winfree, I find you
16 fully qualified.

17 Madam Chairman, I now pass it over to Dr.
18 Matthew Fox for questioning.

19 DR. FOX: Thank you.

20 EXAMINATION

21 DR. FOX: Good evening, Dr. Winfree. I'd
22 like to discuss the non-destructive testing that was
23 performed at NASA Langley and of both the vertical
24 stabilizer and the rudder. The data from these
25 examinations is presented in Exhibit 15B. I'd like to

1 cover -- cover questions about the vertical stabilizer
2 first, followed by questions about the rudder.

3 What techniques did your non-destructive team
4 use at NASA Langley to examine the vertical stabilizer?

5 DR. WINFREE: On the vertical stabilizer, we
6 did ultrasonic testing, impulse echo. We also did some
7 Lamb wave testing which is another acoustic technique,
8 and we also did a thermographic technique.

9 DR. FOX: Okay. For each technique, what
10 type of information related to this accident can be
11 learned about the structure or materials, particularly
12 regarding damage and defects in carbon fiber reinforced
13 polymers?

14 DR. WINFREE: Well, the ultrasonic technique
15 will tell you something about whether or not there's
16 any delaminations. That's the primary thing we were
17 looking at with it. Also, changes in attenuation will
18 tell you whether or not there's any significant micro-
19 cracking formation in the thing. Lamb wave tells you
20 something about the stiffness and also about the
21 thickness of the structure.

22 Thermography is more of a kind of a quick
23 look at the structure to see whether or not you have
24 any delaminations or not. It was kind of primarily
25 done to see whether or not there was some area that we

1 should look at real quickly with the ultrasonics.

2 DR. FOX: Okay. I guess we're still pulling
3 up the audio-visual, but referring to the data
4 presented in Exhibit 15B, particularly for discussing
5 the ultrasound results first that are presented on Page
6 2 to 11, please -- please describe those results for
7 the vertical stabilizer.

8 DR. WINFREE: Okay. Well, what we have -- I
9 believe we have, I guess, the first figure there. Want
10 to go through the ultrasonic signal, first of all, or
11 what?

12 DR. FOX: Sure.

13 THE WITNESS: Okay. Well, I -- in here, it's
14 -- it's on -- on Page 2. There it is right there.
15 What we have is -- is the ultrasonic signal in which,
16 under the top of the page, is -- is the region of the
17 composite that we felt like had no damage in it. What
18 you see is -- this is a pulse echo technique where we
19 have a water column coupling the -- this ultrasound
20 into the -- the composite. As a result of that, what
21 we get is an echo off the front surface. Then assuming
22 there's nothing that blocks the sound from propagating
23 all the way to the back surface, we also get basically
24 an ultrasonic signal off the back surface, and then the
25 third signal that you actually see in there that's of

1 some height, it's actually a reverberation which has
2 gone through the composite two times back and forth.

3 So, one of the things we were looking at is
4 the time of flight which is shown there. Time of
5 flight tells you basically how far back the back
6 surface is in -- in the sample. The other thing we
7 were looking at was the amplitude of the pulse. The
8 amplitude of the pulse tells you whether or not there's
9 significant attenuation has occurred on the ultrasonic
10 signal as it propagated through the -- through the
11 composite.

12 So, in the figure that we show below it, we
13 show a region which, I guess, has an anomaly in it. I
14 guess that's the way to put it. We have an anomalous
15 signal that appears in between the back surface echo
16 and the front surface echo, and in cases where we -- we
17 saw that in the composite, we went ahead and called
18 them out and put them in the thing. One of the things
19 that you'll notice is that when you have that anomalous
20 signal, there's also a significant decrease in the back
21 surface echo and so what we actually show in some of
22 the images that come later on are some of the -- the
23 amplitudes of that back surface signal which is an
24 indication of, in a sense, attenuation.

25 DR. FOX: Okay. So, I guess, looking at time

1 of flight and -- and thickness measurements, how
2 accurately were you able to make those type of
3 measurements?

4 DR. WINFREE: The -- what we were able to do
5 was -- was probably do it with about a 100th of a
6 microsecond, that we were able to do it. So, that's --
7 in that particular case, -- well, it depends on the
8 thickness of the sample. So, off the top of my head,
9 it's probably better than one percent on most of the --
10 most of the samples that we looked at. So.

11 DR. FOX: Okay. Were -- were there any
12 complications associated with -- with lay-up of the
13 composite or -- or local geometries or maybe resin-rich
14 areas versus -- or -- or -- or volume fraction-type
15 differences?

16 DR. WINFREE: Those types of things would
17 give us problems. What we do see is we do see
18 variations in the signal. Probably the biggest problem
19 we have was surface roughness. Surface roughness
20 probably gave us the biggest problem as far as getting
21 a good front surface echo and a back surface echo.

22 The other anomalies that we -- we got in the
23 back surface echo are probably more related to the fact
24 that there seemed to be attachments on the back side,
25 somebody stuck something on the back side for some

1 reason, some kind of damper or something, and we would
2 pick that up and -- and -- but in that particular case,
3 what you don't see is you don't see that echo between
4 the front surface and the back surface. So.

5 DR. FOX: Okay. Perhaps you could describe
6 some of the -- where -- where you did the scans, give
7 maybe a map of --

8 DR. WINFREE: Oh, I think on Page 3, we have
9 the -- the left side, at the top of the page, on Page
10 3. So, at the top, what we show is -- is the area that
11 we cover with the ultrasonic signals. We came down to
12 -- we didn't go into the lugs, but we came down to
13 basically there was a line, that if I remember
14 correctly, was about 10 centimeters above the bottom
15 edge of the tail. That particular line, there was a
16 rise in the pay-in or something and that would happen
17 is every time.

18 The way we did this is we had a latex tube
19 that we used and every time it would go over that line,
20 it would basically break. So, we -- we gave up trying
21 to do both sides of that line. So, what you see at the
22 top is -- is basically time of flight. Y is where we
23 have no data. So, any place where we have a color, we
24 have data, we have time of flight data, and that
25 particular case up in the aft part of the tail, you can

1 see the delamination, the major delamination we found
2 which was quite close to the -- to the surface. I
3 believe it was two millimeters approximately from the
4 -- from the surface, and that was actually visible from
5 the outside of the tail. You could actually see a rise
6 where that delamination was, and, you know, then down
7 below it, we show some of the other delaminations we
8 saw on this particular side of the -- of the tail.

9 DR. FOX: Now, as far as from color, how
10 would we use the color to interpret the results?

11 DR. WINFREE: What the color shows is -- is
12 yellow tends to be shorter times of flight. So, that
13 would be thinner -- thinner parts of the material. As
14 you get into the orange, you get into the thicker parts
15 of the material or actually longer times of flight. In
16 order to actually turn it into thickness, you'd have to
17 know what the velocity was of the material.

18 DR. FOX: Sure. Okay. Let's see. I guess,
19 could we take a look at the -- well, most of the -- in
20 this area, you had -- you saw large delaminations,
21 well, relatively speaking, down at the lower end of --

22 DR. WINFREE: Down -- yeah. Down there.

23 DR. FOX: Were the -- were there any other
24 areas that you had indications or -- or --

25 DR. WINFREE: Well, we had -- we had some

1 small indications which I think we list in all the
2 figures that come after that. So, there's, I think,
3 one at the bottom of that page.

4 DR. FOX: Okay.

5 DR. WINFREE: Actually, if you go to the
6 bottom of that page, you can -- you can see. One of
7 the things we did was we took a schematic of the tail
8 and we put on it boxes where we found -- basically,
9 those boxes outline the regions where the scans are
10 shown in all the subsequent figures. The one being
11 down below it indicates where we saw that echo between
12 the front and back surface, we circled in red. So, we
13 went through all the images, looked at the attenuation
14 images, and only those attenuated areas where basically
15 we saw loss of signal did we circle in red, if we could
16 see the echo between the front and back surface.

17 DR. FOX: Okay. And then, could you show the
18 -- describe the map for the right side?

19 DR. WINFREE: Yeah. The map of the right
20 side is actually on -- on Page -- Page 8 and that, you
21 know, basically the color scale is the same, still
22 yellow is thin, the orange is -- is thicker, and in
23 that particular case, we didn't see any regions where
24 we had delaminations that came out. We still had the
25 same kind of anomalous signals that we -- we reported

1 in the other part, and we also have the schematic and
2 have those laid out on there.

3 DR. FOX: Okay. Thank you.

4 Let's see. I guess perhaps could you discuss
5 some of the complexities associated with the
6 examination in the -- in the lug areas themselves?

7 DR. WINFREE: As far as doing the lugs
8 themselves or what?

9 DR. FOX: Yes, yes.

10 DR. WINFREE: Well, there's -- there is a
11 problem, I think, when you do the lugs basically with a
12 composite material. Basically it's anasyntropic. As a
13 result of that, when you put sound in, it doesn't
14 necessarily go in the direction that you would -- you
15 would think it would go. Basically, it kind of follows
16 something called a slodus curve, which has to do with
17 the anasyntrophy of the material, and so it actually --
18 if the -- the material's highly anasyntropic as this
19 is, actually can follow a curve, so that if you're
20 going to do an inspection, you may put in an
21 ultrasound, and you may think that it's going in the
22 straight rate down to one place, and it may end up in
23 -- in a totally different place in the specimen.

24 DR. FOX: And the lug areas, you observed the
25 Airbus NDE Team inspecting those lugs?

1 DR. WINFREE: They did those inspections,
2 right.

3 DR. FOX: Okay. And what -- what procedures
4 did they use?

5 DR. WINFREE: Oh, they used the pulse echo
6 technique and what they had was they had, in order to
7 help get around some of the problems with it, they had
8 basically delay lines that they put in and the delay
9 lines were angled so that as much as possible, they
10 could get the ultrasound to go in and propagate at
11 surface normal.

12 DR. FOX: Okay. Let's see. I guess the next
13 -- the next topic I'd like to move to is the Lamb wave
14 results for the vertical stabilizer, and could you go
15 over those -- those results for us?

16 DR. WINFREE: Okay. Well, these are -- these
17 -- that's on Page 12. These are showing both the left
18 and right side. These measurements take a considerable
19 amount of time. So, we didn't do as large of an area
20 as we did for the ultrasonics. The principle intent
21 behind this was trying to find regions where there was
22 a significant change in stiffness. They also reflect
23 the thickness of the material which we didn't take out.

24 Down in the -- in the bottom of the one side,
25 the left side, we didn't do measurements because of the

1 curvature as a result of the delaminations. So, we
2 weren't able to -- to get in there. This is kind of a
3 delicate kind of -- it's a technique that we're --
4 we're kind of developing for composite materials. We
5 didn't really see any -- any kind of damage to report
6 in these Lamb wave measurements. So.

7 DR. FOX: Okay.

8 DR. WINFREE: These also -- the ultrasonics
9 does a very good -- well, a reasonably high resolution
10 technique. This is -- is effectively looking at areas
11 that are sampled over about a two and a half centimeter
12 region and as a result of that, they're not going to
13 see some of the small flaws that basically you're going
14 to see with the ultrasonics.

15 DR. FOX: So, at the -- at the lower end of
16 the stabilizer on the left side, where we had the
17 delamination found by ultrasound, the Lamb wave may not
18 necessarily show that?

19 DR. WINFREE: Well, it probably would have
20 shown that if we'd been able to -- to put it over.
21 Like I said, as a result of the -- that curvature,
22 which we had over it, it was hard to get the
23 transducers to lay right on that particular surface.

24 DR. FOX: Okay.

25 DR. WINFREE: But what it would have shown is

1 that -- is a thinning of -- of the surface. If you
2 look at the attached points where the -- you know,
3 about the center, where the hinge points attach in,
4 it's a little bit darker there. That darkness is a
5 result of thickening of -- of the Lamb -- of the
6 composite material. So.

7 DR. FOX: Okay. I guess the next area I'd
8 like to move to is the --

9 ACTING CHAIRMAN CARMODY: Excuse me. Dr.
10 Fox, we have one question from Member Black.

11 DR. FOX: Sure.

12 MEMBER BLACK: Just a question maybe to help
13 me and some of the other people understand it. It
14 appears to be that the dark areas, both in the
15 ultrasound and in the lambda or Lamb -- isn't that the
16 lambda?

17 THE WITNESS: Lamb. No. It's Lamb. It's
18 actually named after a person.

19 MEMBER BLACK: Oh, it's a person. Okay. I
20 thought it was -- who knows.

21 The dark areas are primarily -- are dark
22 because they were close to places where things
23 fractured, are they not?

24 DR. WINFREE: No. Typically, those are --
25 are dark because they're -- it's thicker regions.

1 MEMBER BLACK: They're thicker regions, but
2 they just happen to be at the bottom of the fin where
3 the fractures occurred?

4 DR. WINFREE: Right.

5 MEMBER BLACK: Because it's thicker?

6 DR. WINFREE: Because it's thicker. Right.

7 MEMBER BLACK: Okay. Thank you.

8 ACTING CHAIRMAN CARMODY: Go ahead.

9 DR. FOX: Okay. So, moving -- moving to the
10 -- to the rudder -- well, I guess -- yeah. The -- what
11 techniques did your NDE Team use to -- at NASA Langley
12 to examine the rudder?

13 DR. WINFREE: We looked at it with
14 radiography for -- looking for water content and we
15 looked at it for thermal primarily for water content as
16 well, and then we also did the Lamb wave for more
17 looking at and seeing what the -- how well the face
18 sheet was connected to the subsurface honeycomb.

19 DR. FOX: Okay. So, I guess to some extent,
20 you've described it, but for each technique, you know,
21 what -- what type of information can be learned,
22 particularly with sandwich composites?

23 DR. WINFREE: Well, once again, the primary
24 thing you need from radiography is -- is density or the
25 density along the path of the x-rays, and so if there's

1 any water in there, you should be able to see the
2 water.

3 In the thermal, what you're looking at is --
4 is how fast, if you put a flash sheeting on the front
5 surface, how fast does the front surface cool down? It
6 may -- one of the things it does is if there's any
7 honeycombs attached to the back surface, it cools down
8 faster, not in this particular case, but the primary
9 thing we looked at was -- was the very rapid cooling
10 you got where there was water, and then the Lamb wave,
11 like I said, tells you something about the stiffness of
12 -- of the face sheet and where it's detached, we
13 expected a loss of stiffness.

14 DR. FOX: Okay. I guess, referring to
15 Exhibit 15A, Page 13, could you indicate the areas of
16 the rudder that were examined using these techniques?

17 DR. WINFREE: Well, we -- we -- primarily,
18 there was only one real large part of the rudder that
19 was intact, and that -- that goes from about Hinge 7
20 down to about Hinge 5, I believe.

21 DR. FOX: Maybe Hinge 4? There's -- there's
22 a fracture on the left side at Hinge 4.

23 DR. WINFREE: Let's see. Yeah. I guess it
24 does go all the way. Well, yeah. We went -- we went
25 past Hinge 5 but not -- not all the way down to Hinge

1 4.

2 DR. FOX: Okay.

3 THE WITNESS: Probably about -- I guess if
4 there -- if the fracture was there, we probably went
5 about halfway down between the two.

6 DR. FOX: Okay. So, referring to the -- to
7 the data presented in Exhibit 15B, Pages 13 to 16,
8 could you please describe the results obtained from --
9 from the -- sorry. The results that -- the x-
10 ray/radiography results, I believe.

11 DR. WINFREE: Yeah. Page 13 shows the x-
12 ray/radiography results. In that particular case, what
13 you're -- we have both a blow-up there at the top of
14 the page which shows typical image that we got and what
15 you can see in there is the indications we've got of
16 water which are effectively the white spots. The
17 lettering on there is lettering we put on, lead
18 lettering that we put on there in order to be able to
19 tell which x-ray film we were looking at.

20 You can also see the honeycomb and actually
21 in that piece, you can see where a face -- up at the
22 top of it, a piece of the face sheet was missing on one
23 side, where it's kind of dark there. So, kind of a
24 missing corner right there. So, down -- down at the
25 bottom of that page, we show a composite of all the

1 images put together, and in that particular case, what
2 you see is -- is primarily the water was at the bottom
3 end of the rudder where the most damage was done.

4 DR. FOX: And one thing about the x-ray, it
5 goes through the -- through both --

6 DR. WINFREE: The x-ray does both sides at
7 one time, yeah. So, you -- you -- you can't dispute --
8 you can say it's -- you can say there's water in the
9 honeycomb at that particular position. If you do a
10 single shot, which is what we did in this particular
11 case, alls you can do is -- is determine that it's
12 somewhere along the path. You can't say where along
13 the path it is. In order to be able to do -- with the
14 x-ray, you could be able to do more than one, but it
15 would take doing multiple shots with the x-ray.

16 DR. FOX: Okay. Let's see. I guess the --
17 on Page 14, we've got the results of the Lamb wave.
18 Could you step us through those?

19 DR. WINFREE: Yeah. This is -- this is the
20 Lamb wave and -- and what it -- what you see in there
21 primarily is -- is, I guess, some of the -- the
22 characteristics of like the lightening strap is -- is
23 basically the white strip that goes through there which
24 was actually pretty good for being able to -- to
25 register some of these images with each other.

1 You can also see there's some indications as
2 to where the hinge blocks are at the bottom. The other
3 thing that you notice is there's kind of a white V
4 that's -- it's, I guess, close to the center. It's
5 where that -- that extra piece goes up there and that
6 actually corresponds pretty well with -- with the image
7 that -- on 13 where - where it shows the -- the image
8 where the face sheet has been fractured from the
9 honeycomb. So, that corresponds pretty well with that
10 and probably what it's indicative of.

11 There's also some regions which are a little
12 bit darker than other regions. Those had to do with
13 the fact that there is a ply overlay at this particular
14 point and that gives you a little bit stiffer region in
15 that particular point.

16 The bottom one shows some of the same
17 characteristics. Once again, you can kind of see where
18 if you look on -- on Page 13, where there's -- there's
19 a fractured face sheet and that corresponds pretty well
20 with the Lamb data that you get there, and then you see
21 some of the other characteristics as well of the
22 overlap, the -- the lightening strip and stuff like
23 that. So.

24 DR. FOX: Okay. Thank you.

25 And then, I guess the -- let's see. The --

1 the final technique we have is the thermography, and
2 could you discuss those results?

3 DR. WINFREE: Okay. The -- that's on Page
4 15, and the top just shows two different signals, two
5 different thermal responses that we get after we flash
6 the flashlamps. The one shows the signal that we get
7 if we have just a face sheet with no water entrapped
8 behind it, and below it, we show a cell that basically
9 has water entrapped in it, and what you can see is the
10 significant change in -- in the cooling off, the way it
11 cools off after the flashlamps.

12 We actually, went through and analyzed all
13 the different images we have from that and those are
14 shown in the -- in the next viewgraphs or next images.

15 I guess the best thing to do is probably to go to the
16 next page. Those kind of show the reduced images and
17 then go down to Figure 5.4 to start off with, 5.04, and
18 does the color show up? Well, what we -- what we did
19 was we highlighted in the -- in the color images, you
20 can see we highlighted the regions where -- where these
21 look like they had water, and if you -- actually, if
22 you look at them and you look at the -- once again,
23 back at 13 and look at where there's the -- the face
24 sheet has been detached from the honeycomb, it looks
25 like they correspond pretty well to the -- to the

1 regions where the -- the face sheet is detached from
2 the honeycomb and probably therefore a result of the
3 water getting into Jamaica Bay.

4 DR. FOX: So, -- so, to summarize in general,
5 the results of the -- of the test from the rudder show
6 that the water -- location of the water that you
7 detected from these various techniques seemed to
8 correspond with where you saw visual damage?

9 DR. WINFREE: Where we saw visual damage and
10 also where we saw the detached -- detached honeycomb.
11 Yeah.

12 DR. FOX: Okay. I have no further questions.
13 Thank you.

14 ACTING CHAIRMAN CARMODY: Thank you, Dr. Fox.
15 Any questions from others on the Technical
16 Panel?

17 (No response)

18 ACTING CHAIRMAN CARMODY: All right. Let's
19 move to the parties then. Starting with Airbus, Dr.
20 Lauber?

21 DR. LAUBER: We have no questions for this
22 witness. Thank you.

23 ACTING CHAIRMAN CARMODY: All right. And the
24 FAA, Mr. Donner?

25 MR. DONNER: No questions. Thank you, ma'am.

1 ACTING CHAIRMAN CARMODY: American, Mr.

2 Ahearn?

3 MR. AHEARN: No questions, ma'am. Thank you.

4 ACTING CHAIRMAN CARMODY: And Allied Pilots,
5 Captain Pitts?

6 CAPT. PITTS: Yes, ma'am. I'll be brief.

7 Dr. Winfree, are there effective field non-
8 destructive inspection practices or methods available
9 that can assist operators in the -- in the assurance of
10 the quality of these components, especially in light of
11 the fact as we see the more reliance on the composite
12 structures used in aviation?

13 DR. WINFREE: Are there -- are there
14 techniques already available?

15 CAPT. PITTS: Well, --

16 THE WITNESS: Is that what you're asking?

17 CAPT. PITTS: Sure. I'll break it up. Are
18 there -- are there effective techniques in the field
19 that can be used --

20 DR. WINFREE: Well, typically, what we do
21 with ultrasonic -- excuse me -- with any NDE technique,
22 first of all, somebody defines for us what is a
23 critical flaw, and then when they define the critical
24 flaw, what we do is we establish whether or not there's
25 a technique to find that critical flaw or not.

1 I would say for all things like
2 delaminations, even micro-cracks, I would say there are
3 techniques that already are available that, yes, could
4 go into defining those techniques. As other critical
5 flaws are identified, what we would have to do is -- is
6 on a case-by-case basis decide whether or not they
7 exist.

8 CAPT. PITTS: In the course of this
9 investigation, have you discovered critical flaws in
10 composites that have not been previously identified to
11 you?

12 DR. WINFREE: No.

13 CAPT. PITTS: Thank you, sir. That's all the
14 questions I have.

15 ACTING CHAIRMAN CARMODY: Thank you.

16 Moving to the Board, Member Hammerschmidt and
17 Goglia, Member Black, any questions?

18 MEMBER BLACK: Just one on 15C. Could we put
19 that up? I'm sorry. 15 -- 15C, Page 3. Is this the
20 lug map that we talked about with the Airbus witness
21 previously, the one that is shown to -- in his testing
22 to be the first fail, the right rear?

23 DR. FOX: That's in the analysis that we have
24 so far. The right rear is the lug that is -- is failed
25 first.

1 MEMBER BLACK: Doctor, are your examinations
2 of this area far enough to -- to say whether you found
3 anything in that area that would get your attention?

4 DR. WINFREE: I don't remember finding
5 anything. Actually, Airbus is the one that actually
6 did the inspections on this part of the lug. So.

7 MEMBER BLACK: You didn't look at it?

8 DR. WINFREE: No, not in this particular lug.
9 No, not down in the lug area. Not where it got thick,
10 we didn't look at it. They had special -- like I said,
11 they had special delay lines and transducers that
12 enabled them to -- to put in signals at surface normal.
13 They also looked at -- at different specimens back at
14 their place that were standards. Typically, you don't
15 look at something like this. You need some kind of
16 standard in order to be able to assess whether or not
17 you can really find a flaw or not when it gets in these
18 complex structures.

19 MEMBER BLACK: Thank you.

20 ACTING CHAIRMAN CARMODY: Are there any
21 additional questions from the Technical Panel or any of
22 the parties?

23 (No response)

24 ACTING CHAIRMAN CARMODY: Seeing none.

25 (Whereupon, the witness was excused.)

1 ACTING CHAIRMAN CARMODY: Well, I think that
2 we will adjourn for the evening and start up tomorrow
3 morning at 8. We have two remaining witnesses. So, we
4 should be able to move quickly then.

5 Thank you all for your cooperation. Thanks
6 to the witnesses very much.

7 (Whereupon, at 5:14 p.m., the public hearing
8 was adjourned, to reconvene tomorrow morning, Friday,
9 November 1st, 2002, at 8:00 a.m.)

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25